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ADULT AGE DIFFERENCES IN STROOP EFFECTS:

A CROSS-SECTIONAL COMPARISON

By

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Adult Age Differences in Stroop Effects: A Cross-Sectional Comparison" submitted by Sandra L. Corbin in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The present study was designed to investigate adult age differences in the performance of experimental Stroop Tasks on three factors, and to examine probable sources of age differences in Interference effects.

The literature reviewed included both theory and evidence regarding the source and mechanisms of Stroop effects, and adult age differences in the performance of information processing tasks. Previously identified Stroop factors included: (1) Speed factor; (2) Color-difficulty factor; and (3) Interference. Elderly adults had been demonstrated to exhibit particular difficulty in information processing tasks requiring the focus of attention on specified stimulus or response aspect of the task, and to require longer response times in performance of the Stroop Interference Task.

Three adult age groups: (1) Young, aged 16-25; (2) Middle-aged, aged 35-50; and (3) Old, aged 64-78, were contrasted in the performance of six experimental Stroop Conditions, with repeated measures across four trials. All age group contrasts were on response time measures and derived scores based on response times.

The effect identified as age differential interference was obtained, with the oldest group dxhibiting relatively greater interference on all interference measures; however, the age groups did not differ significantly on other Stroop factors. The results did not support the hypothesis of age differences attributable to acquired differences in association strength. The hypothesis that age differences may be attributable to age-related reduction in efficiency or

effectiveness of selector mechanisms was supported by experimental evidence.

The obtained age differences were discussed both in relation to probable source of age differential interference, and as a possible index of information processing changes with age.

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Task Design

The Stroop Tasks, as they were designed by J. Ridley Stroop in 1935, consisted of the timed administration of lists of three types of stimuli: (1) Color words (e.g., RED, BLUE, GREEN, BROWN, PURPLE) printed in black ink; (2) Color patches representing the same colors named on the color word card; and (3) Conflict stimuli (i.e., color words printed in an incongruent ink color: RED printed in blue ink, GREEN printed in red ink, etc.). Each list was presented in a ten by ten item stimulus array, with items arranged so each of five colors appeared an equal number of times, and repetitive patterns of color were avoided. Color words on the Conflict card appeared an equal number of times in each of the four incongruent ink colors.

Administration of the task involved individual testing with each of the stimulus cards. Stroop asked subjects to read the words printed on cards one and three, and to name the colors of ink on cards two and three. The reading or naming times for each Card X Instruction condition were the dependent measures, with times required to respond to all of the items on the list scored as the response time for each condition. All of Stroop's contrasts were between conditions, with condition means obtained from subjects who were tested in all conditions, on response time scores for each condition.

Modifications in the task design have been made to permit study of the effects described by Stroop (1935; 1937), and to allow between group comparisons and study of individual differences on measures of the interference effect. Alterations in the original task design have taken the form of using different types of stimuli, changes in arrangement of stimuli on the cards, different methods of presentation, and development of various scores.

Variants of the Stroop Task which have been used in studies of individual differences and for between group comparisons on measures of the Stroop effects have generally retained some of the basic features of the original task. As Jensen (1965) noted, most investigators have constructed their own sets of stimulus materials, and have used various methods of administering and scoring the tasks. There are no published versions of the Stroop Task, and with the exception of a factor analytic study resported by Jensen (1965), little information regarding the reliability of scores obtained from measures on the Stroop Tasks.

Research designed to study individual and group differences in Stroop effects has generally involved the measure of individual response times to lists of Color-words, Colors, and Conflict stimuli similar to those described by Stroop. The number of items on each list, the colors used, size of stimuli, and intra-list relation between items have varied across studies. However, the usual administration procedure has been to require each subject to respond once in each of three conditions: (1) C_1 - Read Words on Card one (color words printed in black ink); (2) C_2 - Name Colors on Card two (color patches); and (3) C_3 - Name ink color on Card three (color words

printed in incongruent ink color), in the order C_1, C_2, C_3.

Response times for each condition have usually been measured as the time to respond to all items on the list. In addition to contrasts on response times for the three conditions, correlations and between group comparisons have been made on derived scores developed from differences and ratios of response time measures.

Jensen (1965) reported a factor analytic study of eleven derived and response time measures developed for comparisons on Stroop Task performance. Based on the data from single administrations of the task to a sample of undergraduate university students (N=436), Jensen calculated inter-correlations of the various scores previously reported, and derived both Principle Factor and Vari-Max solutions of the factors involved in Stroop Task measures. The eleven scores used represented considerable redundancy. Jensen concluded that most of the variance in the Stroop Task could be accounted for by three factors, each of which could be represented by a single score. The factors described by Jensen (1965, p.406) were: (1) A Speed factor, possibly representing "personal tempo", and best represented by the response time on C_1; (2) A Color-difficulty factor, indicating difficulty of generating color names to color stimuli, and best represented by the time taken to respond in Condition two with the Speed factor partialed out (i.e., C_2 divided by C_1 plus C_2);and (3) An Interference factor, measuring the delay in Color-naming response in the Conflict Condition, best represented by the derived score Condition three minus Condition two (i.e., C_3 - C_2).

Jensen also tested the reliability of Stroop Task scores by administering the three conditions to one sample of subjects over ten

trials, (N=50). He noted that reliability on most scores was too low for single administration confidence, particularly on derived scores developed as measures of interference (e.g., $C_3 - C_2$). However, with repeated measures, he observed increasing reliability on all scores. Jensen sugested that most of the variance in scores was attributable to practice effects occuring across the first few trials on each condition. Noting that reliabilities on all scores were at acceptable levels when measures were averaged over three trials, Jensen concluded that comparisons on derived scores should only be made with repeated measures.

Individual differences in the Stroop Interference effect have been studied by either correlating obtained measures of interference (e.g., $C_3 - C_2$) with measures obtained on other variables, or by using Stroop Task performance as a criterion variable, and testing for differences in extreme groups on another measure (Jensen and Rohwer, 1966).

Developmental studies of Stroop Interference have generally used the method of contrasting age-defined groups on response times for the three conditions (Comalli, Wapner and Werner, 1962; Jensen and Rohwer, 1966). However, a few studies relevant to adult age differences in Stroop Task performance have used other comparison methods. Comalli, Krus, and Wapner (1965) reported a contrast on response times for two groups of older adults, differing with respect to whether they were living in an institution or were community-living. Bettner, Jarvik and Blum (1971) described a contrast of elderly subjects, with and without diagnosis of Organic Brain Syndrome, on derived scores. Schonfield and Trueman (1974) designed

three variants of the Stroop Task, in which stimuli were color words printed in two ink colors, for administration to five adult age groups in an experimental context.

In the investigation of hypotheses regarding the source and mechanism of the Stroop Interference effect, procedures have been designed to test specific theories; as a result, the stimuli have seldom been presented in the form used by Stroop. "Stroop-like" tasks used to study the effect have differed from Stroop's design in type of stimuli, method of presentation, task requirements, and in the contrasts made.

Source and mechanisms of the Interference effect

The effect which has been described in psychological literature as the "Stroop effect" is manifested in the longer response times required in conditions presenting incongruent or conflicting information, relative to times required to make the same responses in conditions not presenting conflicting information. The delay in responding in "conflict" conditions, whether measured as difference score, or response latency to "interference" items, is assumed to index the capacity of one stimulus attribute to interfere with the processing of another stimulus attribute. As the delay effect has been demonstrated to occur with various stimulus materials and procedures, in addition to those designed by Stroop (1935), it has also been referred to as a "conflict" effect, and an "interference" effect.

Stroop originally designed his tasks as a test of a specific hypothesis regarding the source and mechanism of interference in

"conflict" situations. He was satisfied that the proposed theory was supported (Stroop, 1935;1937). However, as Dyer (1973) noted, continuing research and theoretical formulation regarding the loci and mechanisms of the conflict effect reflects continued dissatisfaction with Stroop's, and with subsequent, explanations of the effect.

Jensen and Rohwer (1966) have remarked that the Stroop effect has been interpreted in so many different ways, and from such unrelated theoretical orientations, a review of the literature is difficult to organize. However, despite many variations on the theme, theories regarding the source and mechanism of the Stroop Interference effect can be categorized according to proposed loci of the effect. On this basis, theories can be described as either: A. Response competition models, proposing an "output" locus of interference at or near the response production stage of information processing; or B. Encoding competition models, proposing "input" loci, at both perceptual and conceptual levels of encoding.

Response Competition

Stroop (1935) proposed a response competition theory to account for interference effects obtained in color-naming responses to incongruent color/word stimulus items. Stroop assumed that Stimulus - Response (S - R) associations acquire different strengths in accord with the number of alternate responses associated with the stimulus. He suggested that the Word - reading response S - R association would be stronger than the Color - naming response association due to differential practice, each word having been associated with a specific reading response, each color having been associated with a variety

of non-verbal responses as well as the naming response. In conflict situations, Stroop predicted that the "stronger" association would dominate. Over a series of six experiments (Stroop, 1935; 1937) Stroop obtained evidence that he interpreted as supporting both the relative strength of association hypothesis, and the differential practice hypothesis regarding the interference effect.

Support for the relative strength of association hypothesis was interpreted on the basis of three lines of evidence: (1) Reading times for lists of color words were faster than naming times for color stimuli; (2) The Reverse Interference effect (i.e., effect of incongruent color attribute on word reading response times) was much smaller than the interference effect of incongruent words on color naming response times; and (3) Response times on card-sorting tasks were faster for color stimuli than for word stimuli.

Stroop's interpretation of this evidence as support for the differential association strength of Word - reading associations was based on the assumption that rates of responding to non-conflict stimuli (e.g., lists of words printed in black ink, color patches in the form of non-word symbols) indexed the strength of association between the presented stimulus and the required response. Relative delays in response time to complex color/word stimuli were assumed to indicate the strength of the competing response. Finding relatively small interference effects of color on word-reading (i.e., the Reverse Stroop effect) compared with the significant interference effect of words on color-naming (i.e., the usual Stroop Interference effect), suggested that the interference effect was due to the dominance of the Word - reading habit. Stroop stated that faster

card-sorting times for color stimuli demonstrated that reading and naming differences were not attributable to faster "recognition" of words, and were predictable on the basis of greater conflict between the Word - reading habit and the Word - sorting response association. He suggested that the Color - naming association, relative to the Color - sorting association, would not be expected to be differentially strong.

Stroop (1937) also provided a test of the hypothesis that practice could create S - R associations of different strength. Using novel stimuli (unfamiliar symbols) Stroop required subjects to learn name responses to stimuli (e.g., blem, hool, nomy, nish) and then assigned the subjects to either Naming only, or Varied response condition. Subjects in the Naming only condition were required to make 1200 naming responses to the stimuli. Subjects in the Varied response condition were also required to make 1200 responses to stimuli, but the responses required included equal numbers of six different types of response (e.g., tapping, collecting, numbering, checking). Following the training, subject groups were contrasted on naming response times. As Stroop predicted, the group given training on naming responses only was significantly faster in the post-training naming trial. Stroop interpreted this finding as a demonstration of the establishment of differential association strength by differential practice.

The response conflict theory proposed by Stroop has not been considered adequate explanation for the effect (Jensen and Rohwer, 1966; Dyer, 1973); however, both the differential strength of association and the differential practice explanation have been cited as

accounting for at least part of the evidence obtained in subsequent studies of the interference effect (Gohlson and Hohle, 1966; Uleman and Reeves, 1971; Nealis, 1974).

Jensen and Rohwer (1966) argued that differential practice as a mechanism for acquiring differential S - R association strength was questionable on the basis of asymptotic levels of performance in responding in reading and naming tasks. Even after extended practice on the two tasks (Jensen, 1965), the rate of reading was considerably faster than the rate of naming. On this basis, Jensen and Rohwer suggested that the difference between Word - reading and Color - naming associations was more likely a difference in complexity than a difference in habit strength.

Treisman and Fearnley (1969) have suggested the nature of the difference in complexity may be the difference in the relationship between stimulus attribute (i.e., word vs. color) and the required response (i.e., verbal naming responses). They speculated that if "color generation" were the required response, the rate of responding to color attributes might be faster than rate of responding to word attributes, and color might interfere more than word.

Dyer (1973) has pointed out that training a variety of responses to word stimuli has not been shown to increase reading response time. He suggested that this would be the best demonstration of differential practice effects.

In addition to conflict with respect to the "cause" of response conflict as proposed by Stroop, later authors have debated the mechanisms of interference and its resolution in the Stroop Interference Task. Klein (1964) suggested that words compete with color-naming

responses by arousal of motor-components antagonistic to the motor-components necessary to produce the color name. He also proposed "re-stimulation" as a mechanism by which the color-naming response would be able to overcome the dominant word-reading response. Assuming that production of the color-naming response required reaching a motor-component arousal threshold, and that motor-antagonism from a competing word-reading response would inhibit reaching that level, Klein suggested that subjects must obtain additional perceptual input from the color attribute in order to produce the required response (i.e., process the color information a second time). Evidence that production of both color-naming and word-reading responses required only slightly longer than production of the color-naming response alone was interpreted as supporting the "re-stimulation" hypothesis.

Klein (1964) also presented evidence that magnitude of interference on a modified Stroop Task was related to semantic association. Response times were measured for lists of words which were: (a) incongruent color/word (i.e., Stroop Interference Condition); (b) color /word of a different color response class : TAN, GREY, BLACK; (c) color/word naming object associated with specific colors in the color response class: LEMON, GRASS, FIRE, SKY; (d) color/common words unrelated to color in meaning or response class: PUT, HEART, TAKE, FRIEND; (e) color/rare words unrelated to color: SOL, HELOT, EFT, ABJURE; (f) color/nonsense syllables: HJH, EVGJE, BHDR, GSXRG.

Interference effects on color-naming response times were greatest in conditions where competition was between responses most closely associated (i.e., color/color word with shared "color" meaning and from the same response class) and decreased as a function of the

reduction in association. Response times for color naming were in the order: color words of different response class > words related in meaning > common unrelated words > uncommon, unrelated words > nonsense syllables.

Klein interpreted the obtained evidence of semantic influence on magnitude of interference as supporting "motor-component" response competition. He suggested that the words used in different conditions of his experiment differed with respect to their capacity to producde arousal (i.e., differed in "attensive power"). "Attensive power" was assumed to be critical in response competition for a single motor-outlet, with more powerful words offering stronger competition for control of the response motor-outlet.

More recent response competition developments of Stroop Interference (Morton, 1969; Dyer, 1973) have involved the building of functional models of the color and word information processing operations which define the locus and mechanism of interference.

Morton (1969) developed a functional model of response interference based on the operations involved in a card sorting task. The Logogen Model, illustrated in Figure 1 , Appendix A, was described as a general model of the "nature of interference". However, with regard to the Stroop Task, it best accounts for the finding of different magnitudes of interference with variation of relation between stimulus attributes.

The proposed model was based on four assumptions: (1) All sensory information is processed in parallel through early perceptual stages of analysis; (2) Information relevant to a single response,

regardless of the source of information, converges on a single "unit" (i.e., logogen) from which the response is made available; (3) There are extensive connections between logogens which are concerned with responses which are related; (4) Word responses are coded in a "Response buffer" memory serially, as they become available, in temporal order.

In the Stroop color-naming task, the required response (i.e., verbal production) would increase the probability that the verbal response to the word attribute would be available for coding in the "Response buffer", prior to the availability of the verbal response to the color attribute. The assumption of serial entry into the "Response buffer" would lead to the prediction that coding of the first available response would delay the coding of subsequently available responses.

Morton's discussion of the connections between logogens, and the interaction of information within the logogen, indicated that response availability is a probability event within this model. The connections between logogens are assumed to function whenever information "flows" through the verbal system, increasing the probability of a response becoming available. In addition, the prior availability of a response is assumed to increase the probability of subsequent availability of the same or related responses. Response primacy was proposed to account for semantic differential effects in Stroop Interference (e.g., Klein, 1964), and Morton's (1969) demonstration of greater interference effects in a sorting task when "required" and "interfering" responses were from the same response set (e.g., digits in a numerosity sorting task).

As can be seen from the schematic of the Logogen Model, Morton proposed parallel processing of information from different modes (e.g., auditory and visual stimulus information) as well as parallel processing of simultaneously presented stimulus aspects within a single mode. This proposition was based on evidence from the card-sorting tasks used by Morton that processing of auditory information did not interfere with processing visually presented information unless information from the two sources was associated. The experimental demonstration of this effect measured card sorting response times in three conditions of auditory presentation. The cards to be sorted according to number of symbols contained between one and six symbols each. The three conditions of auditory material were: (a) spoken words unrelated to numerosity (e.g., low, full, his, big); (b) nonsense syllables (e.g.,"ba"); and (c) digit names one to six. As predicted on the basis of single modality effects, and the assumption that dual modality information could also be processed in parallel, Morton obtained evidence that sorting for numerosity was "interferred with" only by auditory presentation of digit names.

Two other features of the data from this experiment which were remarked on were the "learning effect" in between modality interference, and the critical nature of timing in obtaining an interference effect. The increase in sorting time attributed to interference from spoken digit names diminished across trials, indicating that subjects "learned" to reduce the interference effect. Interference was greatest in early trials, and only occurred in later trials, when the spoken word coincided with the subject's turning up the card to be sorted.

Attempts to obtain evidence of intermodality interference with Stroop stimuli (i.e., interference of spoken color-words on naming colors) have not been successful (Dyer, 1973). Dyer cited a study conducted by Thackray and Jones (1971) which failed to obtain an interference effect in simultaneous presentations of spoken word and visually presented color. He also described experiments he had conducted with failed to demonstrate auditory interference on color processing with varied temporal relation between visual and auditory stimuli.

Interestingly, an effect on interference has been noted when the auditory signals have been "meaningful noise" (e.g., train whistles, bird calls). Houston and Jones (1967) presented Stroop color/word conflict stimuli in conditions with varied simultaneous input, and reported a reduction in the usual interference effect in "meaningful noise" condition. The explanation of this effect offered by Houston(1969) was that inhibition of one signal (auditory noise) facilitates inhibition of the word attribute of the Stroop stimulus item; however, Dyer (1973) suggested that the Houston and Jones noises may slow word processing by eliciting naming responses to the noises. Assuming that the magnitude of the usual Stroop interference effect is related to process timing advantages of word-reading over color naming, the slowing of the word processing might reduce interference by reducing the difference in timing of the two responses.

Dyer (1973) reviewed the experimental evidence and theoretical models of the Stroop Interference effect through 1972. Although noting that Morton's (1969) model was based on demonstration of interference in a card sorting task, and therefore might not describe

all the processing operations involved in a naming task, Dyer concluded that the Logogen Model was essentially representative of the Stroop interference effect.

Two features which Dyer added to the Logogen Model, on the basis of experimental evidence, were emphasis on the inability of subjects to gate or attenuate either color or word information analysis at a perceptual stage, and the importance of either timing or level of analysis to the occurance of interference. Dyer argued that without the parallel processing of sensory information to the level or stage of naming assumed by Morton's model, the Stroop interference effect would not occur. He suggested that the critica

Dyer suggested that the critical nature of the timing of parallel processes from input to response production was supported by two lines of evidence: (1) Evidence that changing the task requirements could effect a change in the relative "interference capacity" of words and colors (Treisman and Fearnley, 1969; Uleman and Reeves, 1971); (2) Evidence that manipulations which affected the rate of word-processing versus color-processing affected both the direction and the magnitude of the interference effect (Gumenick and Glass, 1970; Uleman and Reeves, 1971; Dyer, 1973).

Treisman and Fearnley (1969) demonstrated that presence of conflicting information on either color or word aspect delayed card-sorting responses according to match across attributes (e.g., matching the color of one stimulus item to the word of another stimulus item). Uleman and Reeves (1971) demonstrated that in a scanning task, incongruent color attributes slowed scanning for color word to a greater extent than incongruent words slowed scanning for color.

Dyer (1973) noted that the across attribute matching task designed by Treisman and Fearnley required subjects to transform stimulus information of either color or word attribute in order to make a matching comparison. He suggested that the Stroop Interference Task might be a specific case of general interference when a task requires transformation of the relevant stimulus attribute into another form (e.g., Color into name of color) in the presence of a stimulus attribute close to that form (e.g., word).

Dyer also suggested that the basis of "S - R compatability" might be in the similarity of the word attribute to sensory feedback produced by naming response. If the perception of a word includes an "auditory component", the similarity between the auditory component and sensory feedback from saying the word could be the basis of the stronger connection between word attribute and reading responses.

The Uleman and Reeves (1971) demonstration of "Reverse Interference" in a scanning task was suggested to be indicative of the importance of the requirement to produce naming responses (either overtly or covertly) in obtaining the interference effect of word on color-naming. Other tasks which have failed to produce the usual interference effect of word on color-processing have been checking, tapping, and sorting cards into color-coded boxes (Dyer, 1973).

The importance of process timing has been studied by using single stimulus methods. Stroop Interference stimuli have been presented with varied temporal relation between attributes, and for brief durations, with and without erasure stimuli.

Dyer described variation in the magnitude of interference effects obtained with pre-exposure of color words printed in black ink for varied intervals prior to coloration of the word. With black pre-exposures varied between 0 and 40 msec. durations, Dyer reported longer latency color-naming responses as pre-exposure duration increased. Color-naming response latency was measured from time of coloration of the stimulus. With pre-exposure durations longer than 60 msec., the color-naming response latency was reduced relative to the simultaneous presentation condition. However, responses were delayed by words with pre-exposure durations of up to 500 msec., relative to response latencies obtained with color only stimuli. Dyer suggested that the evidence of an increase in interference with pre-exposure of word attributes for durations up to 60 msec., and reduction in interference with durations of more than 60 msec., indicated that "word-reading activity" may have a time course of between 40 and 60 msec. When color information was presented after the word-reading activity had "died down" (i.e., post 60 msec.), Dyer suggested that color-naming could occur with less interference.

On the assumption that a similar response to the "maximum interference interval" could occur in simultaneous presentation conditions (i.e., subjects wait until reading activity subsides before coding color information) Dyer reported attempts to "mask out" color (Dyer and Kuehne, 1972, cited in Dyer, 1973). Dyer and Kuehne presented color/word stimulus items for durations of 25, 50, 100, 200 and 500 msec., with and without erasure stimulus following the word. They obtained evidence of "normal" interference for duration of 25 msec., without the mask (i.e. longer latency color-naming responses

than obtained for control stimuli presented for the same duration). With the mask following stimulus presentation, there was a small change in the amount of interference observed for stimuli presented for 25 msec. durations, and no change for stimuli presented at longer durations. The change in interference with short duration presentation, followed by erasure stimulus, was in the direction of slightly less interference of word on color-naming.

Dyer interpreted this evidence as suggesting that if subjects wait for word activity to "die down" before coding color information, or "re-stimulate" color information (e.g.,Klein, 1964), they must be able to generate or "re-stimulate" from "non-erasable iconic images of the stimulus color" (Dyer, 1973, p. 118).

Other evidence which could be interpreted as supporting the importance of word versus color time courses, was reported by Gumenick and Glass (1970). Using a screen which partially obscured the words, making them less legible, Gumenick and Glass increased the reading response times to word lists relative to color-naming response times to color lists. With the screen over-lay, the color-naming response times to conflict stimuli was approximately the same as color-naming response times to control color lists (i.e., interference was reduced). Conversely, the slowing in word-reading time appeared to result in greater interference of color on word-reading responses, (i.e., Reverse Interference was appreciably increased). Dyer (1973) reported that although the methodology of Gumenick and Glass was questionable, their results were replicated using more careful controls. It should be noted however, Gumenick and Glass designed their task as a test of the differential habit strength hypothesis, not as a test of

differential time courses.

Closer to a test regarding time courses, Nealis (1974) presented subjects with pairs of stimuli, separated by a short interval. Presenting first conflict color/word stimulus item, followed by either a color matching the color in the conflict stimulus or a row of black X's equal in length to the word in the conflict stimulus, Nealis obtained a retroactive interference effect of color on word-reading. The effect obtained was measured as the difference between the "distraction" effect of black X's on word reading, and the "interference" effect of color on word-reading relative to word-reading without presentation of the second stimulus. Nealis suggested that "reverse interference" is usually much less than "forward interference: for two reasons: (1) Colors "scan" faster than words, and therefore are out of the way more quickly; and (2) The Word - reading response association is an over-learned response (i.e., Stroop's differential association strength explanation).

A third study which bears on the potential of differences in time course for affecting interference was reported by Palef and Olson (1975). The task used was a spatial analogue of the Stroop effect with the position of a word stimulus and the word meaning in conflict (e.g.the word bottom printed to one side). Palef and Olson reported facilitation of the processing of either spatial or word information resulted in an interference shift. With facilitation of word processing, the processing of spatial information was interferred with to a greater degree. With facilitation of spatial processing, word processing times showed greater interference effects. When processing of both aspects were equivalent, interference was bi-directional.

Posner (1978) has also explained the Stroop Interference effect at the level of name codes. In a diagram which paralleled the Logogen Model developed by Morton (1969), and incorporated the critical timing feature suggested by Dyer (1973), Posner suggested that processing of both attributes of the complex stimulus is a parallel operation through the encoding process. The time courses for two internal "look up" operations, producing physical and name code representations, were described as differing in accord with stimulus attribute.

Within Posner's model, shown in Figure 2 , Appendix A, the time course for producing a physical code representation is shorter for color attribute than for word attribute; however, the time course for "look up" of word stimulus name code is faster than production of a name code for the color attribute. The shorter time course for the availability of color attribute "physical codes" than for availability of color attribute "physical codes" might be the basis of the findings regarding brief (25 msec) presentations of color/word stimuli, followed by erasure stimulus (i.e., Dyer and Kuehne, 1972). If Posner's "physical code" is the basis of the "iconic image" suggested by Dyer (1973), the probability of erasing word information presented for 25 msec. might be greater than the probability of erasing color information. Faster name code availability for word attribute was suggested to result in temporal primacy of verbal response to words (Posner, 1978, p.92).

Posner's model accounts for both the occurance of the usual interference effect and the asymmetry of interference (i.e., interference of words on color-naming responses greater than interference of

colors on word-reading responses) by the difference in rate of name-coding. In explanation of the semantic gradient effect (e.g., Klein, 1964; Darlymple-Alford, 1972) Posner suggested that responses which are semantically associated with the required response affect the time reqired for code "look up". Prior responses which are congruent with the required response facilitate, and prior responses which are incongruent with the required response interfere, both due to effects of prior activation on information processing pathways.

Posner cited Warren's (1972; 1974) research which demonstrated pre-activation of the word component by auditory presentation, followed after a brief interval with the complex stimulus, resulted in longer latency color-naming responses. Posner suggested that such "priming" effects can be explained as follows: "..An auditory word activates a pathway in the nervous system that consists of its auditory representation, its name, and a motor program for its production. When the visual word shares some of the same pathway (e.g., name and motor program) its processing rate is increased." (Posner, 1978, p.93).

Response competition theories in general have focussed on the differential availability of color-naming versus word-reading responses. Differences between the theories have been primarily with respect to source of differential availability (e.g., differential practice, differential time course), and with respect to locus of the effect (e.g., response coding, response production). There has been general agreement that some component of the color attribute is processed more quickly than the word attribute, and that both aspects of the color/word stimulus item are processed to a "high level" .

Encoding Competition

At the perceptual level, Treisman and Fearnley (1969) suggested that the asynchrony of the interference effect (i.e., words interfering with color naming to a much greater extent than colors interfer with word reading) might be due to differential selective attention. They suggested that subjects might be able to selectively attend to either word or color when matching within an attribute (e.g., word to word-name) but not when matching across attributes (e.g., color to word-name).

Treisman and Fearnley tested this hypothesis with a card-sorting task which required subjects to sort decks of cards according to five sets of matching instructions. The card decks contained word - word, color - color, and word - color stimulus pairs. Subjects were asked to sort the cards in each deck according to: (1) Word - word match, with and without a conflicting color attribute; (2) Color - color match, with a conflicting word attribute; (3) Color - word match, with color attribute conflicting; and (4) Word - color match, with word attribute of color conflicting. These five sorting conditions represented both across-attribute and within-attribute matching tasks, with interference sources word, color and name. As all responses were sorting responses, which did not require overt word-reading or color-naming responses, the strength of association prediction of interference from the strong Word-read response association was not tested.

Results obtained in this study indicated that card-sorting response times were longer in across-attribute matching conditions (i.e., word matched to color, color matched to word) than in within

attribute matching conditions (i.e., word matching word, color matching color). Also, within-attribute matching times for words and for colors were very similar. These results were interpreted as evidence that at least part of the difference in word-reading versus color-naming times might be due to the greater stimulus - response compatibility between words and color names than between colors and color names.

The effect of a conflicting stimulus attribute, whether word or color, appeared to be minimal on making within-attribute comparisons. However, the effect of either conflicting word or conflicting color attribute was to delay accross-attribute comparisons. This differential effect of conflicting stimulus attribute on across-attribute matching conditions was interpreted as evidence that selective attention (i.e., focussed attribute analysis) may occur in within-attribute, but not across-attribute matching conditions.

Although there are clear distinctions between the matching task used by Treisman and Fearnley, and the traditional Stroop task, the authors suggested that the main sources of interference are the same in both reading and matching tasks. Treisman and Fearnley suggested that under certain stimulus - response conditions, "perceptual-processing" might be facilitated by selective attention to one aspect of the same configuration. Two assumptions implicit in this model of perceptual processing are: (1) Perceptual processing of two or more stimulus attributes requires serial operation at some stage; and (2) Perceptual analysis can be selectively attenuated.

Hock and Egeth (1970) suggested that Stroop Interference occurs

at the stage of implicit color identification or coding of the ink color. They drew a distinction between "low-level" perceptual tasks (e.g., color matching, color counting) which involve "rapidly formed but non-durable stimulus representations formed by the sensing stage of perceptual processing", and "high-level" perceptual tasks (e.g., decision processes regarding whether a color belongs to a specified set of colors). Noting that Klein (1964) had obtained a reduced interference effect on color-naming responses with words not semantically associated to color (e.g., put, take) and that Egeth, Blecker, and Kamlet (1969) had reported no interference effect on a task requiring subjects to make same/different judgements regarding color, Hock and Egeth suggested that interference occurs only when subjects must encode stimuli for "high level" processing.

This hypothesis was tested using the Sternberg (1969) paradigm, in which reaction time is determined for classification of stimuli as members or non-members of a target set. In the Sternberg model, variables which affect the encoding stage result in differences in reaction time (RT) which are constant for different memory set size (i.e., RT as a function of memory set size, encoding variables affect the intercept). Variables which affect central comparisons with memory set result in changes in the slope of RT as a function of memory set size.

Hock and Egeth (1970) contrasted reaction times to three types of stimuli: (1) X's; (2) common words (e.g., RUN, SKIP, DANCE, THROW, LISTEN); and (3) color names (e.g., RED, GREEN BLUE, ORANGE, BROWN, printed in incongruent ink color. Target set sizes of one, two, or three were set for each RT trial, with RT equal to time required to

sort through a deck of twenty cards, making yes/no verbal responses in accord with decisions regarding membership in the target set. Plotting RT as function of memory set size, Hock and Egeth reported finding the expected increase in reaction time with increased target set size, and interaction between type of stimulus material and "classification time" (i.e., longer time required for responding to color-word stimuli than to verbs for all three target set sizes). The Type of stimulus by Target set size interaction was not statistically significant (i.e., no difference in slope).

Hock and Egeth interpreted these results as evidence that verbal material distracted from the identification or encoding stage of processing, but had no effect on the response organization and selection stage of processing. They suggested that the extent to which a task requires "high level" encoding, and is therefore slow, determines the probability of interference. The interference effect was conceptualized as "..the result, rather than the cause, of increased encoding time" (Hock and Egeth, 1970, p.303).

Dyer (1973) has criticized the conclusions of Hock and Egeth (1970) on two bases: (1) Interpretation of the failure to obtain a significant Type of Stimulus by Target Set Size as evidence that verbal material had no effect on response organization or selection stage of processing; and (2) Assumption that the color components of the three types of stimuli used could be encoded at different rates without including covert naming as part of the encoding process.

Dyer's first criticism refered to the use of statistical tests designed to reject one hypothesis as the basis for accepting an

alternate hypothesis. Although this would be an error regardless, conclusions are further compromised when the non-significant effect is an interaction. As Dyer pointed out, the failure to obtain a significant interaction may reflect "imprecision in the experiment" rather than non-existence of the interaction.

The second criticism was based on Dyer's assumption that the memory set of the target colors is probably in the form of color names. If this assumption is made, then the task of encoding stimuli for making a memory match (i.e., deciding same/different set) should involve covert generation of the names of color stimuli. Dyer argued that it would be at the stage of generating name responses that the interference effects occur. Following covert or overt word responses, no further interference would be expected. Dyer, following Dalrymple-Alford and Azkoul (1972), concluded that Type of Stimulus would not be expected to interact with Target Set Size, because the response competition between color name responses generated for color and word aspects of the conflict stimulus would have occured prior to the same/different set decision.

Seymour (1977) constructed a conceptual encoding model of the Stroop Interference effect, illustrated in Figure IIIa, Appèndix A. He suggested that interference occurs at the level of conceptual representation, and derives from the semantic conflict brought about by the simultaneous analysis of both aspects of the stimulus. The principle proposed was: " Processing delays occur whenever discrete semantic codes are simultaneously activated; greater delays occur when conflicting codes are values on a single dimension or closely related dimensions".

Arguing that the usual color/word stimulus materials used in the Stroop Task result in a confounding of encoding and response competition processes, Seymour designed new tasks to test competing predictions made within three models: Conceptual encoding; Response competition; and Morton's (1969) Logogen Model. The task designed by Seymour used season names (e.g., winter, summer) in place of color words, and colors associated with seasons as color attributes (e.g., winter associated with white, summer associated with yellow, autumn associated with brown). In addition to the usual congruent/incongruent manipulation, Seymour used relations between seasons (i.e., opposite, after, before) in the construction of stimulus-response configurations.

Seymour's subjects were asked to respond to presented stimuli either with Direct responses (e.g., "say the name of the color associated with the season","say the name of the season associated with the color") or with Indirect responses (e.g. "say the name of the season opposite to that associated with the print color", "say the name of the color opposite to that associated with the season"). These four conditions were assumed analogous to the Stroop Task conditions of interference on word on color-naming, and interference of color on word-reading. An additional transformation operation was included by requiring Indirect responses.

Seymour suggested that the three interference models predicted the same order of response times in Direct response conditions. The relation "same" (e.g., winter printed in white ink) should lead to faster response times than the relations "before" (e.g., winter printed in green ink), the relation "after" (e.g., winter printed in

brown ink), or the relation "opposite" (e.g., winter printed in yellow ink). Seymour also suggested that all three models predicted Direct responses would be faster than Indirect (e.g., "winter" responses to the word winter printed in white ink would be faster than "summer responses to winter printed in white ink). These predictions were based on the assumption that all three models would predict faster responses in conditions which did not require a transformation of the response.

Predictions differentiating between models were made within the Indirect condition (i.e., "opposite" naming). Seymour interpreted the three models as making different predictions with respect to which relations between display word and display color would facilitate response time relative to response times for other relations. Specifically, he suggested the Conceptual Encoding model predicted facilitation in the "same" relation condition (e.g., winter printed in white, correct response: "summer"), the Response Competition model predicted facilitation in the "opposite" relation condition (e.g., summer printed in white ink, correct response: "summer), and the Logogen model predicted facilitation in both "same" and "opposite" relation conditions.

These predictions were based on the assumption the three models suggested alternate mechanisms of interference, as well as different loci of the interference effect. The Conceptual Encoding model attributes interference to serial encoding of semantic information. As the "same" relation provided the subject with redundant semantic information, encoding of semantic information was speeded, and the

response facilitated. The Response Competition model was interpreted as suggesting that interference occurs due to serial response production. As the "opposite" relation provides the subject with the required response as the distractor attribute of the stimulus, Seymour suggested the Response Competition model would predict facilitation of response in the "opposite" relation condition. The Logogen model, described by Morton (1969), provides for activation of the logogen by input from any source. Seymour suggested that the Logogen model would predict facilitation of response in both "opposite" and "same" relation conditions, as graphemic, phonologic and semantic information were assumed to be equivalent "response primers", capable of increasing the probability of coding and producing the associated response.

Seymour (1977) reported the results from data analysis on four experiments with tasks which were variations on the theme described above. He interpreted the data as evidence supporting the Conceptual Encoding model. Primarily due to failure to demonstrate facilitation of responses with "opposite" relation between display word and color, he concluded that the results were a disconfirmation of both the Response Competition and Logogen models.

Seymour suggested that the Conceptual Encoding model should include two "lexical interface" structures. The structures he proposed serve to: (1) Provide <u>Access</u> to semantic memory for the operations of graphemic to semantic conversion, and chromatic to semantic conversion; and (2) Provide <u>Exit</u> from semantic memory for the operation semantic to phonological conversion. Seymour suggested

these structures on the basis of evidence that graphemic information congruent with the phonological response did not facilitate responses. When the display word was the correct response in the Indirect Condition,responses were not faster than when the display words were "other".

Seymour's tasks were more difficult than the usual Stroop tasks, and obtained higher than usual error rates. In addition, variance which appeared attributable to differences in the associative strength of season - color pairs (e.g., winter - white versus summer - yellow) resulted in a significant between colors effect, and a significant Color by Relation interaction. The transformation operation appeared to introduce an additional source (or sources) or interference. Although such effects were not statisticall significant in all reported experiments, they introduced sources of variance which have not been factors in the more usual Stroop Tasks.

Despite the complexity and possible introduction of additional factors in the task developed to test the model, the model itself is relatively simple. Seymour has described three operation stages: (1) Conceptual encoding; (2) Semantic transformation; and (3) Response selection and production. Semantic transformation is an optional stage, following conversions graphemic to semantic or chromatic to semantic, and must occur in conditions such as the Indirect response condition. Seymour did not suggest a mechanism for the resolution of ambiguity in the Logogen system.

A conceptual Encoding model is supported by evidence that the capacity of words to interfere with color-naming appears in a semantic gradient (e.g., Klein, 1964). The finding of interference as

a function of semantic association has been replicated with other forms of the Stroop task, and with frequency of word occurance controlled (Proctor, 1978). In addition, Darlymple-Alford (1972), using a single item presentation method, demonstrated that words congruent in association, but not meaning (e.g., LEMON printed in yellow ink), resulted in faster response times than words unrelated to color (e.g., DANCE, printed in yellow). However, Darlymple-Alford (1972b) has also demonstrated that phonological similarity between stimulus aspects can increase interference (e.g., QUEEN printed in red, BED printed in green) relative to unrelated and dissimilar stimulus aspects.

Encoding competition theories in general have specified "input" loci for interference effects. However, with the exception of Treisman and Fearnley (1969) "within-attribute" matching condition, there has been general agreement that competition occurs at "high level" perceptual processing stages (Hock and Egeth, 1971), or conceptual encoding stages (Seymour, 1977). As encoding competition theories have moved to "higher" levels or "later" stages of processing, and response competition theories have included consideration of coding of responses, discrimination between the two types of theory has become more fine. Although conflict continues regarding the locus of the Stroop Interference effect, a recent discussion by Kahneman (1973) pointed up the fading distinction. Kahneman described the Stroop Interference effect as "response competition", due to conflict in "encoding" color and word information.

As may be seen from the variety of manipulations which have affected the magnitude and direction of interference effects with

"Stroop-like" tasks, interference probably occurs at more than one locus, and from more than one source. Although an apparantly simple task, the Stroop Interference Task requires a complex chain of responses prior to overt production of the color or word name.

Individual and Age Differences: Evidence and implications of differences in Stroop effects

Individual Differences

In a review of the literature regarding individual differences in Stroop Task performance, Jensen and Rohwer (1966) described a large body of research which has been concerned with determining the relation between intelligence, age, race, sex, psychiatric diagnosis, personality, drug reactions, cognitive style, perceptual-motor task performance, and the factors involved in Stroop task performance.

Studies regarding relation between measures of personality, race, spychiatric diagnosis, perceptual-motor task performance and measures on the Stroop Tasks have generally provided negative evidence.

Jensen and Rohwer cited evidence from extensive studies conducted by Thurston and Mellinger (1953) and Jensen (1965) which indicated that personality factors probably account for a small proportion of the variance in Stroop Task performance (Jensen and Rohwer, 1966, pp.76-83). The only study reviewed which examined the relation between race and Stroop Tasks was conducted in 1925, and compared ten and twelve year old Negro and Caucasian children on reading and color naming speeds. Obtained differences (i.e., black children were slower on both measures at age 10, no significant

differences at age 12) were interpreted as attributable to differences in learning history. There would be no theoretical reason for expecting race differences in interference effects.

Psychiatric diagnosis has not been demonstrated to be related to performance on Stroop Tasks, except in interaction with length of institutionalization (Smith and Nyman, 1962, cited by Jensen and Rohwer, 1966) and in the case of diagnosis of Organic Brain Syndrome (Bettner, Jarvik and Blum, 1971). Shagass and Schwartz (1960) found a significant relation between age and Stroop Task performance across all diagnostic categories. Smith and Nyman (1962), although failing to obtain significant differences between diagnostic categor- on any of the usual Stroop measures, reported differences between "improving" versus "non-improving" patients on a serial scoring method of contrast. The serial scoring method compared response times for each consecutive set of 20 items, and discriminated relatively consistent performance, consistently deteriorating performance, and fluctuating performance. Bettner, et al. (1971) reported subjects with diagnosis of Organic Brain Syndrome performed more slowly on the three Stroop Task conditions; however, only the color difficulty factor was shown to discriminate between diagnostic groups, and that was significant only for females.

Perceptual-motor task performance measures have been demonstrated to be related to the Speed factor in Stroop Task performance. However, with respect to Interference and Color-difficulty factors, the relationship has been tenuous. Jensen and Rohwer concluded that where significant correlations have been found between perceptual tasks and Stroop Task performance, the perceptual task

has usually contained "some cognitive or problem-solving aspect" Jensen and Rohwer, 1966, p.72).

The relation between measures of Stroop Task performance and intelligence has also been described as "tenuous" (Jensen and Rohwer, 1966, p. 74). Jensen (1965) reported that the correlation between Progressive Matrices and the Color-difficultly Factor was significant, but small. Although there has been little indication that measures of general intelligence are related to Stroop Task performance, as Jensen and Rohwer have noted, most studies of the Stroop effects have used college students as subjects. Correlations between two variables would not be expected to be high when one has been restricted to a narrow range (Jensen and Rohwer, 1966, p.74).

Stroop Task performance has been demonstrated to be affected by drug ingestion. Jensen and Rohwer (1966, p. 66-68) reviewed a series of studies conducted by Callaway and his associates which were designed to test hypotheses regarding the effect of stimulant and depressive drugs on the focus of attention, under the assumption that "narrow attention" would reduce interference, "broad attention" would increase interference effects. The hypotheses were suggested to be supported on the basis of the lower interference scores (i.e., $C_3 - C_2$) obtained by groups of subjects administered methamphetamine, and higher interference scores for groups receiveing barbituates, relative to subjects receiving placebos.

Sex differences have generally been reported to be non-significant on the Interference and Speed Factors of the Stroop Tasks; however, significant differences have been noted on the Color-

difficulty factor (Jensen, 1965; Jensen and Rohwer, 1966) and on color-naming speed (Stroop, 1935). Stroop interpreted the faster color naming by female college students as due to differential practice, assuming that females have been trained to be more responsive to color.

Studies of individual differences in cognitive style which have used Stroop Interference scores as a criterion measure to define extreme groups have demonstrated differences in the performance of "high interference" and "low interference" subjects (e.g., on a size estimation task, "low interference" subjects tended to over-estimate, and "high interference" subjects tended to under-estimate the standard). However, the studies which have provided correlation data on "cognitive style" and Stroop Interference scores have generally reported small correlations between the measures (Jensen and Rohwer, 1966).

Jensen and Rohwer interpreted the finding of significant relations between Stroop Task performance and various measures of "cognitive style", with small correlations between measures, as indicating the nature of the Stroop Task factors. They suggested that Stroop Task performance involves factors which are probably basic, and have implications for performance on most other cognitive and perceptual tasks; however, the generality of the factors involved in Stroop Task performance would result in their poor predictive ability with regard to more specific factors (Jensen and Rohwer, 1966, pp. 85-86).

Age Differences

Age differences in performance of the Stroop Tasks have been studied both developmentally (Ligon, 1932; Jensen and Rohwer, 1966) and in connection with aging (Smith and Nyman, 1962; Comalli, Wapner and Werner, 1962; Bettner, Jarvik and Blum, 1971; Schonfield and Trueman, 1974).

Ligon (1932) tested children between the ages of six and eighteen on speed of word-reading and color-naming. Although he found increases in speed on both measures with age, he noted the magnitude of the difference between reading and color-naming speeds did not differ significantly across age groups. On this basis he suggested that differences in reading and color-naming speeds were attributable to factors other than the differential practice of stimulus - response associations.

Stroop (1935) criticized use of absolute differences in response speeds as the between age groups contrast. He stated that when comparisons were based on "relative rates of responding" to colors and words (i.e., ratio of word-reading/color-naming responses per 100 seconds) the difference between responses could be seen to increase with age.

A comprehensive study of the relation between age and Stroop Task performance was reported by Comalli, Wapner and Werner (1962). Comalli, et al., using a single administration procedure, tested 256 subjects between the ages of seven and eighty with the three Stroop condition lists. They reported significant age group differences, and a significant Age by Conditon interaction. The form of

the interaction is illustrated graphically in Figure 3 , Appendix A. Reading and Color-naming response times on non-interference conditions were reduced across age groups between the ages seven through seventeen, and were relatively stable across age groups seventeen through eighty. The interference condition reflected improvement with age between the ages seven and seventeen, relative stability between the ages seventeen and forty-four, and longer response times for the sixty-five to eighty year old subject group. Significant differences between groups on difference scores were obtained using a Median Test, showing cases above and below the median to differ significantly between age groups. Comalli, et al. did not report between age group differences in ratios of rates of responding to color and words; however, the response times for these conditions appeared to be maintained in roughly the same ratio across the eleven age groups.

In a subsequent study, Comalli, Krus and Wapner (1965) contrasted two samples of subjects aged sixty-five to eighty years. The data of the oldest group described in the Comalli, Wapner and Werner (1962) study were contrasted with data obtained from an institutionalized sample. Elderly subjects in the earlier study had been community-living members of an "old-age club". The second sample were all residents of a nursing home. Comalli, et al.(1965) reported longer response times by the institutionalized group on all three conditions, and differentially longer times on the Interference condition.

Smity and Nyman (1962) reported differences across age groups in serial scoring of the Interference card. The method used by Smith

and Nyman involved measuring performance time on the Interference condition for each twenty responses, rather than for the total number of responses. For the age groups studied, twelve to sixty year olds, Smith and Nyman obtained evidence of a reduction in within-card imporvement, and a reduction in within-subject variability on repeated measures, with age. They did not include measures on color-naming without a source of interference.

In a study which included measures of Stroop Task performance as a possible correlate of Organic Brain Syndrome diagnosis, Bettner, Jarvik and Blum (1971) contrasted elderly male and female subjects on both response time and the derived scores suggested by Jensen (1965). Bettner, et al. reported significant sex and diagnosis differences on all three conditions, with females reading and naming at faster rates than males. Female subjects with the diagnosis of OBS demonstrated higher scores on the Color-difficulty factor. Organic Syndrome subjects of both sexes demonstrated longer response times on both interference and non-interference color-naming conditions. There were no significant between group differences on either the Speed factor or the Interference factor.

In a discussion of these results, Bettner et al. pointed out that all subjects were community-living, rather than institutionalized. They suggested that further deteriouration of the "with OBS" subjects might result in greater between group differences on Interference and Speed factors of the Stroop Task. The finding of significant sex differences in all response times was interpreted in the context of the higher incidence of circulatory disease in the male population. Bettner, et al. suggested that circulatory

disease might be expected to slow responses generally. With respect to the finding of greater Color-difficulty scores for female OBS subjects, Bettner, Jarvik and Blum suggested that the greater responsiveness of women to color (Stroop, 1935) might also result in greater sensitivity of this score to loss for women with minimal brain damage.

In a study designed to test a specific hypothesis regarding age differences in performance on information processing tasks, reported by Schonfield and Trueman (1974), modified Stroop stimuli were used as test materials. Age groups ranging in age from twenty to seventy years were given timed trials on four types of stimulus lists: (1) Traditional Stroop color/word conflict stimuli; (2) Color words printed in two ink colors, first half of the word in a color congruent with the word, second half incongruent; (3) Color words printed in two ink colors, first half incongruent and second half congruent with the word; and (4) Color words printed in two ink colors, both halves incongruent. Schonfield and Trueman required all subjects to name ink colors in all conditions. Condition one was the usual Stroop Interference condition. Condition two through four required a double response, naming both ink colors. As expected, the double response required more time for all subjects.

Results of this study indicated that the age differential Stroop Interference effect, reported by Comalli, et al.(1962), was probably obtained. Response times on Condition one were approximately equivalent for the age groups 20 through 50, were slightly longer for the 50 to 60 year olds, and were significantly longer for the group aged 60 through 70. However, the non-interference condition (i.e.,

naming colors in the color-only condition) was not included in the study. The predicted reduction in magnitude of the differential Stroop Interference effect was obtained on Condition two. Although requiring two responses on Conditions two, three and four resulted in longer response times than obtained in Condition one for all age groups, the increase in response times between Conditions one and two was smaller for the oldest group than for the younger age groups. Age differences in response times for Conditions three and four, which also required two responses, were of larger magnitude than for Condition one or Condition two.

Schonfield and Trueman (1974) interpreted the smaller age differences in Condition two as reflecting a reduction in the interference effect for the oldest group when they were permitted to make the "dominant" response (i.e., the response congruent with the word-reading response). This interpretation was in accord with differential strength of association explanations of age differences in information processing described by Schonfield (1975), and discussed in detail below.

Implications for theory of Stroop effects

Studies conducted on developmental and individual differences in Stroop Task performance have generally been conducted under assumptions regarding the nature of Stroop effects, rather than as tests of those assumptions. However, evidence from these studies may be applied to existing theories regarding the source and mechanisms of Stroop effects.

Most individual differences studies conducted with the Stroop Tasks have either used Stroop Task performance as a criterion measure,

or have tested the relation between performance on Stroop Tasks and other measures by determining the correlation between measures. Citing failure to obtain significant correlations between Stroop Task performance and performance on other measures, despite demonstrated relations with Stroop performance as a criterion variable, Jensen and Rohwer (1966) have suggested factors involved in the Stroop Task are "basic" and common to many tasks. The tasks which have been demonstrated to be related to Stroop performance (e.g., size estimation, embedded figures) have been primarily problem-solving tasks, or measures of "cognitive style", on tasks which require relatively complex information processing.

Although not definitive, accumulated evidence indicates small correlation between perceptual-motor task performance and Stroop Task performance. This would not support either early perceptual encoding, or late motor-component response conflict explanations of the Stroop Interference effect.

Developmental research which has demonstrated the relation between reading and color-naming response times, as well as a change in the magnitude of "interference effects" with age (Comalli, Wapner and Werner, 1962), has provided negative evidence regarding differential practice. Contrary to the differential practice explanation of acquired differences in response strength, the relation between reading response times and color-naming response times appeared to remain relatively constant across the age span seven to eighty. Although the results were not reported as "rate-of-responding" ratios, the reduction in response time for reading color words in black ink across ages seven to nineteen was shown to be paralleled

by a reduction in response times for naming color of ink patches (see Figure IVa.). Moreover, the mean times for the reading and naming responses did not appear to change with age across the nineteen to eighty year old span, despite presumable extended "differential practice".

If the assumed relation between differential response strength and interference were to be supported, the "interference effect" would be expected to increase with age and acquired strength of the reading response. Instead, across the age groups seven to nineteen, response times on all three measures were seen to decrease. In addition, the response times for reading and color-naming appeared to remain relatively stable across the adult age span measured; however, the mean interference effect was appreciably greater for the sixty-five to eighty year old group than for the younger adult groups.

Evidence contradicting the proposed relation between relative reading and color-naming response strengths, and the "interference effect" has also been provided by Jensen's (1965) intercorrelation of Stroop measures. The correlation reported between the ratio of reading and color-naming response times and interference, as measured by the difference between Interference Card color-naming response times and non-Interference Card color-naming response times (i.e., $C_3 - C_2$) was non-significant, $r_{436} = .02$.

The evidence from developmental and individual differences research can be, at best, interpreted as suggestive with respect to the nature of the Stroop Interference effect. However, based on lack of evidence from these sources, neither differential strength of association due to differential practice, nor the perceptual

encoding models appear to be supported. Both the curvilinear relation between Stroop Interference and age (Comalli, Wapner, and Werner, 1962), and the tendency for Stroop performance to correlate more positively with problem-solving task performance, may indicate the importance of cognitive processes in Stroop performance.

It should be noted that most of the between group contrasts reviewed were performed on data collected in single administration testing. The extent to whcih between group differences in adaptation to task demands may have contributed to the finding of between group differences in Stroop performance, has not been examined.

Implications for between group differences

Jensen's (1965) factor analytic study of the Stroop Task provided evidence that usual measures of performance on the tasks describe three relatively pure factors: Speed, Color-difficulty, and Interference. Of these three factors, the Interference factor has been of greatest experimental interest. However, the nature of "interference proneness" has not been clarified by correlation with other performance measures.

Evidence of significant, but small, correlations between Stroop Interference and other measures has been interpreted as indicating that the Interference factor enters into a "broad spectrum of psychological phenomena"(Jensen and Rohwer, 1966, p.85). The generality of the factor has not contributed to an understanding of the meaning of individual and group differences on interference measures. At present, differences between groups in Stroop Task performance can not be used to precisely describe the source of differences, nor to predict other differences.

Age Differences in Information Processing: Theory and evidence

As reflected in the Psychology of Aging literature, the area of age-related changes in information processing has excited considerable research interest. Evidence of adult age differences in performance measures on a variety of experimental tasks has resulted in the development of competing "aging" theories of information processing, and the generation of methodological debate regarding appropriate interpretation of the evidence.

Various Interference models, reviewed below, have been proposed to explain and predict age differences in the processing of information. Interference models in general have been based on the proposition of changes with age in susceptibility to interference effects. Different models of interference have been proposed to account for age-related changes in behavior at various experimentally defined "levels" of processing. Both peripheral and central processing mechanisms have been suggested as loci of age-related changes.

Alternate explanations of evidence for age-related changes in information processing have included the arguement that older subjects exhibit a general slowing in the processing of information, and the suggestion that age differences are attributable to changes in strategy, motivation, or adaptability with age.

Methodological criticism of research related to adult age differences in information processing has been focussed on the issues of appropriate experimental design and adequate controls permitting an "aging" interpretation of results.

Interference Theory and Evidence

Models of change in interference effects with advancing age have been proposed to account for age differences in the processing of information at almost every behavioral level. Far from a unified "theory of interference", however, the literature reflects many different and unrelated hypotheses and ad hoc explanations of experimental results. As Craik (1977) pointed out, although age differences have freguently been attributed to "interference effects", lack of consensus regarding the term "interference" has created problems in interpreting the evidence.

In the interest of organization, suggested loci and mechanisms of age differential interference effects have been desicussed below under the headings of Selective attention, and Strength of association.

<u>Selective</u> <u>Attention</u>:

Aging changes in selective mechanisms have been suggested both in the form of increasing focus of attention (Rabbitt, 1965; Schonfield, 1975; Craik, 1977), and in the form of more diffuse attention with advancing age (Kausler and Kleim, 1978). In addition, age changes have been suggested both with regard to capacity to selectively attend stimuli, and with regard to ability to maintain a specified response set (Comalli, Wapner and Werner, 1962).

Focussed Attention

The proposition that old adults exhibit decrements in information processing tasks relative to younger adults due to more focussed attention has been based primarily on differences in performance on

perceptual and learning tasks. Older subjects have been shown to require longer search times to identify target stimuli, and to be differentially disadvantaged by increased amounts of irrelevant stimuli in the display (Rabbitt, 1965). Rabbitt interpreted this data as evidence of a reduction in the "perceptual span" with age. He suggested that older subjects are particularly disadvantaged in conditions with increased amounts of irrelevant information because this places stress on the limited processing capacity of the aging system.

Other evidence which has been cited as supporting the hypothesis of less difuse attention in old age has been obtained in contrasts of performance on divided attention tasks, and with incidental learning paradigms. Craik described evidence that older subjects are differentially penalized in tasks requiring division of attention between "..two input sources, input and holding, or holding and responding" Craik, 1977, p.388-392). The types of task which have demonstrated this effect include dichotic listening tasks, serial reaction time tasks, and the performance of two tasks simultaneously (e.g., visual letter cancellation task and monitoring series of auditority presented letters for repeated letter). Older subjects have appeared to concentrate attention on one task or channel, where possible, and to perform poorly with respect to the other. In the serial reaction time task, subjects were required to monitor and key press responses to a display of lights. Older subjects were significantly slower in conditions which required them to respond to signals previously displayed (i.e., divided attention between memory and response).

Craik suggested two interpretations of the divided attention deficit: (1) Older subjects are less able to "switch" attention rapidly between stimuli, or between processing operations; or, (2) Older subjects have a reduced processing capacity.

Mergler, Dusek and Hoyer (1977), on the basis of results obtained in an age groups contrast on recall memory for target items, and recognition memory for incidental items, suggested that the incidental memory performance of old subjects reflected a reduction in processing capacity. Stimulus items for recall memory were pictures of household items (e.g., desk, chair) paired with pictures of animals. Subjects were teated for recall of names of household items by the probe method, asking subjects to name the object presented in a specified ordinal position (central, or target recall task). Following a series of presentation and probe trials, the pictures of animals and objects were presented separately, and subjects were asked to identify the previously presented pairs (incidental recognition task). Performance scores on both recall and recognition tasks were lower for old subjects than for young subjects. Mergler, et al. argued that if the attention allocation of older adults were more diffuse than that of younger adults, performance of older subjects on the recognition task should have been superior to that of young subjects.

Schonfield (1975) has proposed age differences in focus of attention, related to the strength of association between presented stimulus items and the elicited response. He has suggested that differential strength of association accounts for age differences in the performance of "interference tasks" (i.e., any task which requires

the suppression of one response and the expression of another). An integral part of Schonfield's theory is the suggestion of greater difficulty in switching attention in old age. Schonfield described age decrements in "interference tasks" (e.g., Stroop Task, proactive interference learning tasks) as due to greater difficulty in over-coming or inhibiting a strong association, including "..inhibition of temporary associations receiving attention at a particular moment."

The Stimulus persistence model, proposed by Axelrod, Thompson, and Cohen (1968), has been suggested as a mechanism which could account for increased difficulty in switching attention, and explain apparent increases in focus of attention (Botwinick, 1973). Axelrod, Thompson and Cohen proposed the "Stimulus persistence" model as a principle source of increased "noise" in the aging nervous system. As they described the principle:

> In the senescent nervous system, there may be an increased persistence of the activity evoked by a stimulus, i.e.., the rate of recovery from the short-term effects of stimulation may be slowed. On the assumption that perception of the second stimulus as a discrete event depends on the degree to which the neural effects of the first have subsided, the poorer temporal resolution in senescence would then follow.
> Axelrod, Thompson and Cohen, 1968, p.193.

Although stimulus persistence could be considered a misnomer, as "the activity evoked by a stimulus" has generally been termed a response, the basis of the Stimulus persistence model is the suggestion of differential slowing in "rate of recovery".

Axelrod et al. proposed stimulus persistence as a source of age-related interference effect on the basis of previous studies in which

older subjects had demonstrated lower thresholds for Critical Flicker Fusion (CFF) and Critical Click Fusion (CCF), (Weiss, 1963; Weale, 1965). Both CFF and CCF measure the pulsing rate at which a stimulus is judged to be "continuous on". The pulsing rate at which "continuous on" judgements are made is termed the "threshold for fusion". Axelrod, et al. suggested that a persisting "stimulus trace" would be perceived as filling the inter-stimulus interval (ISI), and would thereby lower the fusion threshold.

As a test of this model, Axelrod, et al. contrasted old and young subjects on a tactile analogue of the fusion task. Discrete mild shocks were administered to the fingers of one hand, or the fingers of both hands, with varied ISIs. Thresholds for perceiving the shocks as a single event were lower for older adults, and the age differences were greater when shocks were applied to fingers of opposite hands. The authors interpreted this evidence as support for the Stimulus persistence model. They suggested that the increased age difference with greater spatial separation might be due to greater loss in precision with involvement of more synapses. Other direct tests of the Stimulus persistence model have been described by Schonfield (1975), Atkeson (1978), Kline and Orme-Rogers (1978) and Walsh and Thompson (1978).

Schonfield (1975) reported "suggestive" evidence of stimulus persistence in a contrast of three adult age groups on a duration of visual after-image measure. Although reported differences were nonsignificant, Schonfield noted that the data of the oldest age group (subjects over age 60), tended to be in the direction predicted by the Stimulus persistence model. Older subjects reported longer

duration after images. There were no apparent age differences in the after-image duration for young and middle-aged subjects. Schonfield suggested that failure to demonstrate any evidence of stimulus persistence in the data of middle-aged subjects might indicate the effect was due to aging changes specific to old age.

Atkeson (1978) contrasted subject groups aged twenty to seventy-nine on sequentially and simultaneously presented Müller-Lyer stimuli (i.e., >——<——> , and >——< ISI <——>). She suggested that if older subjects perceive stimuli as persisting, they would be susceptible to the illusion that the second stimulus line is shorter in the sequential presentation condition. The results of length judgements indicated that subjects between the ages sixty to sixty-nine were susceptible to the illusion in the sequential presentation condition. The effect was more pronounced in the simultaneous presentation condition for this group also. Subjects aged twenty to sixty made length judgements which indicated presence of the illusion effect in the simultaneous, but not the sequential presentation condition. Subjects aged seventy to seventy-nine did not demonstrate positive illusion effects in the sequential presentation condition, and demonstrated "weak" illusion effects with simultaneously presented stimuli. Atkeson interpreted these results for the "young-old" (i.e., aged sixty to sixty-nine) as in accord with the Stimulus persistence model. She suggested that aging effects might include selective loss of "damping" (i.e., inhibitory) neurons at the onset of old age. The "weak" illusion demonstrated by the "old-old" subjects (i.e., aged seventy to seventy-nine) in the simultaneous presentation condition, and absence of illusion effect on judgements made in sequential

presentation condition, were attributed to more generalized loss with advancing old age (i.e., loss of both excitatory and inhibitory function).

The most convincing demonstration of stimulus persistence was made with a sequential integration of form task, conducted by Kline and Orme-Rogers (1978). These authors designed a word identification task which required the integration of sequentially presented word-halves. The word-halves were presented for durations of twenty and forty msecs., with ISIs of 0, 60 and 120 msecs. Although word identification scores varied as a function of both duration of signal and ISI between word halves for both age groups, with longer duration and shorter ISIs associated with more correct identifications, older subjects identified more words correctly than did young subjects in all conditions. In addition, the age difference favoring old subjects was greatest at the shortest duration (i.e. 20 msec.) and longest ISI (i.e., 120 msec.). Kline and Orme-Rogers interpreted these results as strong evidence supporting the Stimulus persistence model, suggesting that the persistence of the stimulus trace resulted in effectively longer duration of stimuli, and shorter duration of ISIs.

In addition to direct evidence from the threshold, illusion and integration studies cited, Botwinick (1973) has provided a comprehensive application of the Stimulus persistence model in post hoc explanation of age differences in more complex judgement tasks, perceptual illusions, selective attention in learning and memory tasks, and behavioral rigidity. Botwinick suggested far-reaching consequences of Stimulus persistence. Citing results in which older subjects

were shown to be relatively less inaccurate in making judgements regarding the equivalence of weights presented successively than in judgements of weights presented simultaneously, Botwinick suggested that stimulus persistence would have the effect of maintaining the standard. Noting that older subjects have been shown to be less susceptible to the perception of oscillation in the Necker Cube illusion, and in spiral after-effect illusions, Botwinick suggested that such illusions may be more difficult to establish because the persistence of the stimulus trace creates an inertia effect. He cited evidence which indicated that if the spiral after-effect can be established for older subjects, it may be of longer duration.

Although Botwinick acknowledged that the Stimulus persistence model "best fits" data obtained with serial perception tasks (e.g., CCF, CCF thresholds), he argued that increased perceived duration of stimuli, and the resultant distortion of information would also be expected to affect behavior generally. He suggested that older adults may appear to be relatively unresponsive to, and modified less by, new experiences and new information due to the effects of distorted perception of their environment.

A cautionary note was appended by Fozard, Wolf, Bell, McFarland, and Podlosky (1977). In describing the hypothesized effects of stimulus persistence on complex behaviors, they noted that the measures of complex information processing and problem-solving tasks, index chains of responses. As a result, the potential role of persisting stimulus traces may be difficult to assess.

Diffuse attention

In contrast to the "focussed attention" models, Kausler and Kleim (1978) have suggested that age-related decrements in perceptual search tasks, and in recognition and recall memory performance, are related to less selective attention with increasing age. In a test of this hypothesis, Kausler and Kleim contrasted the performance of young and old subjects on recall and recognition memory for target words, and incidental distractor words. Target words, those instructed for recall, were presented with one or three distractor words. In accord with their predictions, the recall scores for target stimuli were higher for old subjects in the condition presenting only one distractor, than in the condition presenting three distractor words. Recall schors for the target words were higher for young subjects in the condition presenting more distractors. Later tests of recognition memory for the distractor words presented in the two target learning conditions indicated that although young subjects recognized more of the distractors presented in both conditions, the relation between age group, recognition score, and presentation condition was in the direction predicted by more diffuse attention with age. The older subjects correctly identified more of the distractors presented in sets of four words, relative to their recognition scores on distractors presented in sets of two words, than did young subjects.

Kausler and Kleim interpreted this data as evidence of decreased ability to selectively attend stimuli in an array, with increased age. They suggested that performance on both recall and recognition tasks would be degraded by less selective attention to stimuli, as diffuse

attention would be expected to result in less effective and durable encoding of both target and incidental stimuli.

Most suggestions of change in selective mechanisms have been concerned with attention to stimulus set properties, and have discussed age-related reduction in capacity or efficiency of processing in perceptual terms. A departure from this method of analysis was provided by Comalli, Wapner, and Werner (1962), who proposed decrements in ability to differentiate responses, and to maintain a specified response set in old age.

Comalli, Wapner and Werner formulated their hypothesis regarding "aging" changes in information processing the the context of a Comparative-developmental theory. The general principal of the theory is that "development entails an increase in differentiation and hierarchic integration of functions" (Comalli, et al., 1962, p. 47). Under the assumptions that responses to stimuli represent differentiated functions, and that maintenance of both selective attention to stimulus aspect and selective attention to specified response requires hierarchic integration of function, Comalli et al. suggested developmental differences across the life span. They considered mature adult behavior representative of the "differentiated" and "integrated" state. Behavior of children and aged individuals was predicted on the basis of their maturation level relative to young adults. Children were suggested to represent an "immature" state, and therefore a less "differentiated" and less "integrated" state. The aged were suggested to display a similarly "less differentiated and hierarchically integrated" state, under the assumption that aging involves developmental "regression".

Comalli, et al. suggested that the extreme young groups and oldest age groups would demonstrate relatively poorer performance on interference tasks such as the Stroop Interference condition, due to reduced ability to selectively attend the color stimulus aspect, and reduced ability to maintain a response set to "name colors" rather than " read words". They interpreted results indicating similarly long response times on the Interference Condition for children and the aged adult subjects as supporting the hypothesis that differentiation and integration of function vary across the life-span, and the "regression" hypothesis regarding behavior in old age.

The Signal-to-Noise model of aging changes proposed by Welford (1965) suggests a mechanism providing increased interference with age which would be expected to be in accord with hypotheses of more diffuse attention to stimuli, and perhaps with reduced discrimination of responses. Welford (1965) proposed an Interference model which suggested information processing deficits in old age due to a gradual shift in the ratio of processed "signal-to-noise" (S/N). Older subjects were described as being presented with a lower ratio of S/N in all information processing tasks, both at input (i.e., external source) and within in the system (i.e., internal source). The shift in S/N ratio was attributed to loss of selectivity, integrety and efficiency in the aging nervous system, leading to increases in processing of "non-signal" information.

The Signal-to-Noise model of interference was proposed in the context of age differences in performance on simple Reaction Time and perceptual speed tasks; however, the consequences of a shift to

lower ratio S/N (e.g., loss of discrimination power, greater difficulty in detecting signals, and general behavior slowing) were predicted to affect performance on information processing tasks in general (Welford, 1965; Schonfield, 1975).

Subsequent evidence of age differential decrements in performance on visual discrimination tasks (Talland, 1966), and auditory discrimination tasks (Warren, Wagner and Herman, 1978) with presentation of stimuli in low ratios of signal-to-noise has been interpreted as supporting the S/N model. However, the lack of specificity with regard to locus or nature of "noise" in the S/N model has resulted in a shortage of differential tests. Schonfiled (1975) noted that the S/N model does not predict "proportionate" versus "disproportionate" age differences. In fact, although it was proposed as an "interference" model, it does not provide criterion which would discriminate the S/N model from a general reduction in the rate of information processing.

Strength of Association

Hypotheses proposing changes in the strength of association between stimuli and responses, and changes in competition between associations, have been suggested in connection with age differences in recall memory performance (Craik, 1977), in learning (Arenberg and Robertson-Tchabo, 1977), and in a variety of perceptual and performance response conflict tasks (Schonfield and Trueman,1974; Schonfield, 1975).

Craik (1977) in a review of evidence interpreted as supporting age differential "interference effects", in performance of memory tasks, suggested a Stimulus - Response model of interference. He

noted that S - R models describe interference in Response competition terms, and argued that existing data regarding age differences in memory performance could best be described as Response competition increases with age. As response competition would be expected to increase as a function of the number of responses associated with a single stimulus, Craik suggested that older adults may acquire a greater "functional" number of responses associated with each retrieval cue or stimulus. An additional, or alternate mechanism suggested for increasing response competition was that "selector mechanisms" may be less effective in old age. "Appropriate" and "inappropriate" response sets, assumed to be differentiated by "selector mechanisms", would be expected to increase in competition as a function of greater inertia or reduction in discriminatory power in selector mechanisms with age.

Although increases in the number of "functional " responses associated with each stimulus, and loss of efficiency in selector mechanisms, could be seen as affecting both encoding and retrieval processes, Craik suggested a retrieval locus of interference effects. He suggested that having processed two or more bits of information, the older subjects may have differential difficulty discriminating the appropriate response.

Arenberg and Robertson-Tchabo (1977) reviewed evidence of increased interference effects with age from studies conducted with proactive and retroactive interference paradigms. Proactive interference (i.e., effect of previous learning on learning new material) data reviewed was interpreted as supporting hypotheses of age-differential interference. Old subjects have been shown to perform

relatively better in learning lists of paired associates which are "high associates" (e.g., hot-cold, blossom-flower) than in learning lists of unrelated word pairs (e.g., flower-act, song-cold), and the differences between conditions have been shown to be greater for old subjects than for young subjects. Similarly, old subjects have been shown to be differentially disadvantaged when the task requires learning word pairs constructed of "high associates" paired with words other than the associated word (e.g., hot-blossom, cold-flower). Arenbert and Robertson-Tchabo interpreted the results on proactive interference tasks as suggesting old subjects are differentially benefited by well-established Stimulus - Response habits when the strongest association provides the appropriate response, and differentially disadvantaged when the strongest association is an inappropriate response.

Evidence of age differences in retroactive interference (i.e., effect of new learning on performance of previously learned responses) was reported to be equivocal. Both positive and negative results with respect to age differences in anticipation learning of paired associate lists were cited. Arenberg and Robertson-Tchabo noted that the difference in results appeared attributable to differences in pacing of the tasks. In anticipation learning paradigms, the learning and test components of the task occur in every trial. Subjects are presented with the stimulus word for a fixed interval, followed by presentation of the paired response word. The interval between onset of the stimulus word and onset of the response word, termed the anticipation interval, is the time allowed for responding.

The duration of the interval in which both stimulus and response are presented, is termed the inspection interval. Studies which demonstrated age differences in retroactive interference were conducted at a rapid pace (e.g., one second anticipation); studies which did not demonstrate age differences were conducted at a slower pace (e.g., 3.5 - 4 second anticipation). Other studies cited indicated that when both inspection interval and anticipation interval were varied, older subjects were differentially benefited by longer anticipation intervals.

Arenberg and Robertson-Tchabo concluded that evaluation of age differences in retroactive interference effects is complicated by the difficulty of equating rate of learning the two sets of stimuli; however, the significance of the length of anticipation interval would indicate that if age differences in retroactive interference are significant, the effect is probably in retrieval or selection of the appropriate response (i.e., response competition).

Schonfield (1975) provided a generalization regarding age differences in responding in "conflict" situation which proposed "disproportionately powerful" associations with increasing age. The principle of Schonfield's theory, as he expressed it is: "Stronger associations in a hierarchy, including a strong temporary association at the focus of attention, tend to be disproportionately powerful as age increases." The inclusion of "temporary associations at the focus of attention" indicated a potential for "interference effects" from irrelevant, "distracting" stimuli; however, Schonfield's discussion of the proposed mechanism focussed on the effects of competing S - R associations of extablished differential habit strength. The

evidence cited as supporting a differential association strength explanation included choice reaction time, learning, perceptual and behavior "rigidity" studies.

Schonfield described disproportionate age differences in reaction time when the correct response required pressing a key on the side opposite to the ear in which a tone was presented, relative to "same side" key press reaction time. He suggested that the "same side" S - R represented a strong association, and that making the "opposite side" response required overcoming a predominant S - R association. With respect to age differences in interference effects on learning, Schonfield noted that older subjects have been suggested to be more susceptible to "negative transfer" effects (i.e., inhibitory effect of learning on subsequent learning), and having greater difficulty in "reorganizing habits". Citing age differences in learning lists of aired associates with varied association strength, and on performance in "mirror drawing" tasks, Schonfield suggested that the "power of old associations" would account for age differences in learning new S - R associations.

Age differential Stroop interference effects, and age-related decrements in performance on embedded figures, ambiguous figures, and in processing sequential visual information were described as illustrative of the difficulty experienced by older subjects when experimental tasks require inhibition of the strong association, or existing "percept". Schonfield suggested that the principle of stronger associations is related to behavioral "rigidity", and is demonstrated in tasks which require alternation between tasks, or sets.

In a study conducted with variants of the Stroop task, Schonfield and Trueman (1974) demonstrated that older subjects were relatively less disadvantaged in an interference condition which required subjects to make the response congruent with the Word - reading response, prior to making the incongruent color-naming response. Schonfield and Trueman interpreted the smaller age difference in this condition, compared to conditions requiring the incongruent response first, as due to the removal of the necessity to inhibit the strong competing association. They suggested that age differences in interference on the Stroop tasks are attributable to the greater difficulty experienced by older subjects in inhibiting the Word-read association.

Alternate Explanations of Age Differences in Information Processing

Despite the prevalence of interference hypotheses in the "Aging" literature, alternate explanations of the obtained differences in task performance have been offered. Two prominant alternatives have been the suggestion that obtained differences are attributable to a general slowing in the rate of information processing with age, and the proposition that changes in strategy, motivation, or adaptability, rather than in capacity, occur with increased age.

Rate Slowing

In the context of a review of evidence regarding cognitive decline with advancing age, Kinsborne (1977) noted that the most reliable evidence of age differences has been on measures of performance on speeded tasks. This has held for both between age group

comparisons and longitudnal measures. Kinsborne suggested that without evidence of qualitative differences between age groups in manner of processing of information, there is no basis for proposed changes in either capacity or strategy of information processing. He argued that data presented as evidence of age differences in information processing has generally been in a direction predictable on the basis of a slowing in the rate of processing.

Evidence interpreted as supporting the general slowing explanation of age differences has been of two types: (1) Negative findings in research designed to test for between age group differences in direction of responding to changes in experimental condition; and (2) Demonstrations of between age group difference in rates of processing.

As an example of negative support, Simon and Pouraghabager(1978) designed a complex Choice Reaction Time task as a test of three hypotheses regarding the source of differential age effects. Based on Sternberg's (1969) Additive Factor logic, the authors formulated hypotheses which predicted differential interactions as support for specific sources of age differences. The sources tested were age differential effects on reaction time, response selection, and stimulus discrimination as a result of irrelevant information presented at various stages of processing. As the only significant effects obtained were Main effects: Age, Stimulus Quality, and an Interaction between Age and Stimulus Quality, Simon and Pouraghabagher concluded that age differences in the processing operations required by this task were in rate of processing. However, as they acknowledged, failure to obtain statistically significant interaction effects could not

be interpreted as evidence of no differential interference effects.

Another study which was reported as failing to support age differential interference effects was conducted as a test of the Stimulus Persistence model. Walsh and Thompson (1978) reported the results of an age agroups contrast using the Haber and Standing Direct Measure procedure (Haber and Standing, 1969). The procedure involved measurement of the maximum ISI duration required for perception of cycling target stimuli as a fixed visual display.

Walsh and Thompson varied target duration between ten and ninety msecs., and presented cyclic flashes of the target stimuli (symetrical letter Os) in both monoptic and dichoptic viewing conditions to all subjects. The measure of longest ISI at which the letter was perceived as fixed was determined by the method of ascending and descending limits, with ISI changed in 25 msec. increments. At all target durations, and for both monoptic and dichoptic presentations, the ISIs at which old subjects judged the stimulus as "continuous on" were shorter than the ISI "continuous on" judgements of the young subjects. Contrasts of group means collapsed across conditions indicated that the stimulus could be interpreted as having "persisted" 15% longer for young subjects, using this procedure. Walsh and Thompson interpreted the results of their study as clear disconfirmation of the Stimulus Persistence model. In a discussion of the results, they described the Haber and Standing procedure as providing data regarding "centrally mediated visual storage". This interpretation was based on the equivalence of ISI measures obtained in both monoptic and dichoptic presentation conditions, and lack of evidence of effect on persistence judgements in conditions of reduced luminance.

Although the threshold differences on CFF measures, frequently cited as supporting "stimulus persistence" appear to counter the results obtained by Walsh and Thompson, differences may be in level of analysis. Fozard, et al. (1977) have described CFF measures as susceptible to effects of changes in the pupil diameter and opacity of the crystalline lens. Walsh and Thompson have noted that age differences in CFF threshold are small, and may reflect age differences in peripheral structure. In addition, Fozard, et al. have described age differences in the variability of CFF thresholds, suggested to account for part of the demonstrated age difference.

Other studies which have provided evidence of age differences in the rate of processing information include contrasts on visual backward masking (Kline and Szafran, 1975; Walsh, 1976) and on a complex reaction time task (Gaylord and Marsh, 1975).

The results from visual backward masking studies (Kline and Sxafran, 1975; Walsh, 1976) have been interpreted as supporting longer processing time requirements of older adults. The interval between onset of target stimulus (TS) and onset of masking stimulus (MS), termed Stimulus Onset Asynchrony (SOA) was the measure of contrast in both studies. Minimum SOA duration permitting correct report of the TS has been described as an index of the time required for processing stimuli.

Walsh described the procedure used in his study as a "central masking procedure". Using the dichoptic presentation method, with TS and MS presented to opposite eyes, equal luminance of TS and MS, and a pattern MS, he argued the masking procedure would permit peripheral processing, but mask stimuli at the central processing level.

The SOAs required by older subjects to escape the masking effect averaged 24% longer than SOAs required by young subjects. Walsh interpreted the evidence of age differences as supporting a slower rate of central processing for older subjects. Walsh suggested three possible age-related operation changes which could result in central processing slowing: (1) Increase in operation time at each processing stage; (2) Redundancy of operations, with repeated sampling of prior level information by some process(es); and (3) Increase in number of processes involved.

Gaylord and Marsh (1975) also provided a test of differences in the rate of central processing. The study designed contrasted old and young subjects on a reaction time task, in which cognitive processing time (i.e., time required for mental rotation of a perspectively drawn figure, and to determine whether it was congruent or incongruent with a standard) and residual reaction time (i.e., time required for perception, motor response, etc.) were partitioned. The objective of the research was to determine whether older subjects differed in rate of processing from young subjects on both components of the total reaction time.

The procedure used by Gaylord and Marsh required the plotting of reaction time as a function of degrees of difference between the two presented figures. Reaction time (RT) is partitioned: $RT=a_0 + a_1D$, where a_0 equals residual RT, and is derived at the intercept; a_1 equals cognitive processing RT and is derived from the slope of the curve; and D equals the degrees of difference between figures.

Gaylord and Marsh demonstrated that the ratios of processing times for Old and Young subjects differed on the mental rotation and

residual processes. Old subjects required 84% more time for "residual" and 139% more time for "cognitive" processes. Gaylord and Marsh interpreted their results as supporting a central processing slowing, as well as peripheral RT slowing with age (i.e.,general slowing); however, it should be noted that the age differences appeared to be greater for "cognitive" processes.

<u>Age differences in strategy, motivation, and adaptability</u>

In connection with both perceptual judgements (Botwinick, 1973; Fozard, et al., 1977), and performance of more complex learning and memory tasks (Bromley, 1964; Hulicka, 1965), it has been argued that at least part of the "age differences" effect may be attributable to differences in strategy, motivation, or adaptability to experimental situations.

Botwinick (1973) described a proposed relation between "stimulus persistence" and behavioural rigidity; however, in an earlier study (Rees and Botwinick, 1971) an age-related "conservative bias" in decision-making was described as unrelated to ability to discriminate stimuli. The Rees and Botwinick study used an auditory signal-detection method, and contrasted threshold of signal detectability and decision criterion of subject groups. They reported older subjects set higher levels of decision criterion, with signal detectability matched statistically. This was interpreted as evidence of an age-related shift in response bias, with older subjects adopting a conservative criterion in making judgements regarding the presence or absence of a signal.

Fozard, et al. (1977) offered a similar explanation for age-related increases in variability of CFF threshold judgements. Noting

that even when old and young subject groups did not differ with respect to mean threshold, they did differ with respect to within subject and within group variability, Fozard et al. suggested that older subjects were more variable with respect to setting criterion for making judgements.

Both Bromley (1964) and Hulicka (1965) have described age differences in performance on learning and memory tasks, particularly in incidental paradigms, as being at least partially attributable to the adoption by older subjects of a more selective strategy. Hulicka described this as learning to attend to critical stimuli in the environment. Although she considered the change to be one of strategy, rather than a change in information processing capacity, it could also be seen as a change in strategy in response to a change in capacity.

Age differences in motivation have been argued as reflecting the "reduced achievement motivation" of older adults, with the resuld that older subjects set lower goals and strive less in experimental situations than do younger subjects (Okun, 1976). However, the opposite proposition, that older subjects perform less well than younger subjects due to anxiety and over-arousal in the experimental situation, has also been suggested (Eisdorfer, Nowlin and Wilkie, 1970).

Age changes in ability to adapt to the unique demands of the experimental task, particularly in conditions which are not encountered in the extra-experimental environment, have been suggested as a source of age differences in many studies. In the context of a discussion of the age differences obtained by Schonfield and Trueman (1974), Fozard, et al.(1977) suggested that older subjects may have required more time

to adapt to the novel requirements of the task. Noting that older adults may be better adapted than young subjects to "conventional color-name configurations", Fozard et al. argued that they may be correspondingly more sensitive to the "disruptive context effects" of unconventional color-name configurations in the Stroop Interference Task.

It seems doubtful that even old subjects have a long history of reading color words printed in congruent ink colors. Nor are they more likely to have become accustomed to naming two ink colors in the order congruent - incongruent, than to naming two ink colors in the order incongruent - congruent. However, the suggestion that older adults may require longer to adapt to the task requirements seems particularly relevant in a task which has been demonstrated to be strongly affected by practice (Jensen, 1965).

Physiological evidence regarding functional age differences

Signal-to-Noise and Stimulus Persistence models of interference, and the slowing in rate of processing explanations of age differences have proposed age changes in the nervous system as correlates of behavioral change. Although integration of evidence regarding age differences on both physiological and performance measures would be expected to provide a clearer definition of age-related change, few studies have been conducted from this perspective. In consequence, the relation between age differences in the structure and function of the nervous system has not been experimentally defined, and remains primarily speculative.

The Stimulus Persistence model proposed age-related loss of inhibitory processes, and consequent slower rate of recovery from the effect of stimuli in the nervous system (Axelrod, et al.,1968). Eisdorfer, Nowlin and Wilkie (1970), suggested that in the aging nervous system there is a selective loss of "damping" (i.e., inhibitory) neurons.

More diffuse and generalized loss has been suggested within the Signal-to-Noise and rate-slowing explanations of behavior change with age. Welford (1965) suggested general loss in selectivity, efficiency, and integrety of the nervous system, resulting in the processing of more "noise" with age. The physiological bases of age-related slowing in peripheral processing have been suggested by evidence of changes in sensory threshold (Fozard, et al., 1977) and reduction in speed and efficiency of nerve conduction (Welford, 1977). Structural, metabolic, and neurochemical changes in the CNS (Beck, 1978) and in the ANS (Eisdorfer, Nowlin, and Wilke, 1970) have been suggested as underlying changes in rate of central processing.

Beck (1978) reviewed evidence regarding functional implications of neurophysiological deterioration with age. Interpreting the evidence of morphologic, metabolic and behavior changes with age, Beck suggested that metabolic changes may be more highly correlated with changes in function with age than structural changes. Although structrual evidence of neural degeneration (e.g., diffuse cell loss, neurofibril tangles, accumulation of lipofuscin and plaques containing amyloid) appears to be positively correlated with behavioral evidence of senile dementia (Jarvik, 1975; Miller, 1977; Beck, 1978), the relation between degenerative changes and "normal" aging has not been clearly

defined (Jarvik, 1975). The metabolic changes described include general deterioration of biochemical anabolic functions (i.e., synthesis) reduction in glucose oxidation, reduction in the release, effect and uptake of neurotransmitters, and increase in catabolism of neurotransmitters.

Beck (1978) cited evidence suggesting a possible selective bias in structural change (i.e., evidence of cell loss in hippocampus and substantia nigra) among samples of behaviorally "normal" aged, and in neurotransmitter balance (i.e., hypofunction of dopaminergic system, resulting in a shift in ratio of acetylcholine to dopamine.

Evidence of age-related changes in the hippocampal cholinergic system, and bias in neurotransmitter balance, are of particular interest due to the similarity between behavioral symptoms associated with these pathologies and behavior associated with "normal aging". Damage to the hippocampal cholinergic system has been associated with persistence in current or habitual modes of response, failure to habituate to novel stimuli, and reduction in adjustment to change in reinforcement contingencies. These behaviors have been suggested to be characteristic, in mild form, of "normal" aged individuals.

In describing the implications of a shift in ratio of acetylcholine to dopamine, due to hypofunction of the dopaminergic system, Beck cited an hypothesis of Parkinsonian bias in the aging nervous system. The potential explanatory value of the connection between the neurochemical balance associated with Parkinson's disease and the neurochemical balance associated with aging, can be seen in a description of the behavior characteristic of Parkinsonian pathology: "..slowness of movement,tardy movement initiation, diminished kinetic

grace, reduction in CFF threshold, persistence in error responses.." Beck, 1978, p. 420). In a less exaggerated form, these behavior signs are considered characteristic of normal aging.

Evidence based on bio-electric measures has been equivocal with respect to implications regarding the nature of age-differences in CNS and ANS resting levels of activity with performance measures. Both "under-arousal" hyptheses, corresponding to rate-slowing and diffuse attention explanations of behavioral change with age, and "over-arousal" hypotheses, which would be in accord with "focussed attention" explanations of age-changes in information processing, have been proposed.

Marsh and Thompson (1977) in describing the competing arousal theories, have pointed out that evidence interpreted as supporting an "under-arousal" hypothesis has been derived primarily from resting CNS measures (e.g., EEG shift to lower frequency, smaller amplitude signals) and reductions in autonomic reactivity in conditioning paradigms (e.g., measures of blood-levels of catecholamines). Support for an "over-arousal" hypothesis has been obtained in measures of averaged evoked response (e.g., higher amplitude early components of visual averaged evoked responses), and high blood levels of free-fatty acids.

Although the physiological evidence of "aging" cited above represents a superficial review of the physiological literature, it does reflect the lack of clear connection between behavioral measures on information processing tasks, and physiological status. Relationships between measures require more investigation, and until the evidence is available, remain speculative. As Botwinick stated, behavioral models "may, or may not reflect physiological reality" (Botwinick,1973,p.189).

FORMULATION OF EXPERIMENTAL HYPOTHESES

Purpose:

The present study was conducted for the purpose of investigating adult age differences in the performance of Stroop Tasks. Previous research has described adults over age sixty as demonstrating "differential interference effects" in the performance of these tasks; however, alternate explanations of the age effect have been provided.

The objectives of the present study were to: (1) Determine whether the reported adult age differences in Stroop Task performance were replicable using procedures which controlled for potentially biasing variables; and (2) Test alternate hypotheses regarding the nature of age differential interference effects.

Rationale:

In order to meet the objectives of the study, it was necessary to: (1) Establish that the Stroop effects were being measured by the experimental procedure; (2) Determine whether the age groups tested differed with respect to the magnitude or direction of the measured effects; and (3) Determine whether age group differences in Stroop Task performance were attributable to: (a) Decrease in old age of efficiency or effectiveness of "selector mechanisms"; or (b) Increase in old age of strength of "strong associations".

Experimental hypotheses regarding the Stroop effects were based on previous evidence of differences in response times across stimulus and response conditions (Stroop, 1935; 1937; Klein, 1964),

differences in response times across trials (Stroop, 1935; Jensen, 1965) and interactions between experimental condition and trial effects (Stroop, 1935; Jensen, 1965).

Experimental hypotheses regarding the nature of adult age differences in Stroop Task performance were based on previous evidence of differential effects, and alternate explanations offered to account for differential interference effects in the response times of aged subjects. The hypothesis attributing age differential interference effects to "aging"-related decrease in efficiency or effectiveness of "selector mechanisms" was based on the research and interpretations of Comalli, Wapner and Werner, (1962), Schonfield (1975), and Craik (1977). The hypothesis attributing age differential interference effects to differential strength of associations was based on the research of Schonfield and Trueman (1974) and the interpretations of Schonfield (1975).

Other explanations of the reported longer response times of elderly subjects in "interference conditions" were also examined. These included the possibility that old subjects process all information at a slower rate than do younger subjects (Kinsborne, 1977), and the possibility that older subjects require more trials to become "adapted" to the task demands (Fozard, Wolf, Bell, McFarland, and Podlosky, 1977). Other factors only tangentially related to age, or unrelated to age, but considered potential contributors to the between group differences described as an age differential interference effect (e.g., sex differences, differences in education or usual occupation,) were used as selection or matching criteria.

Stroop Effects

All prior evidence and theory regarding sources and mechanisms of Stroop effects led to the predictions of differences in response times for reading and naming response conditions, and for interference and non-interference conditions. Within interference conditions, greater interference effects have been obtained with color words, than with non-color words (e.g., Klein, 1964), or with colors as the interfering attribute (Stroop, 1935; Dyer, 1973). These effects have been obtained both in contrasts on response time measures between experimental conditions (Stroop, 1935; Klein, 1964) and in contrasts on derived difference scores indexing interference effects (Jensen, 1965; Dyer, 1973).

The differences in magnitude of interference effects obtained in the usual Stroop Interference Condition (i.e., naming ink color of incongruent color/word stimulus items), in the Unrelated word Condition (i.e., naming ink color of color/verb stimulus items) and in the Reverse Stroop Interference Condition (i.e., reading words of incongruent color/word stimulus items), have been attributed to various sources. Stroop (1935) described the relatively greater interference effects of words on color-naming as due to the differences in association strength. The word-reading response was assumed to be a stronger habit, and therefore the dominant response in competition, regardless of response instructions. Treisman and Fearnley (1969), suggested that subjects may be able to selectively attend words in a verbal response condition, but are unable to selectively attend color when the required response is a verbal naming response.

Dyer (1973) and Posner (1978) have suggested that verbal responses or codes for word information, are available prior to responses or codes for color information; therefore, the color response was suggested to interfere less because of the relatively longer time course between input of color information and availability of color name.

Likewise, the relatively smaller interference effect obtained in Unrelated word Interference conditions has been given more than one explanation. Klein (1964) described this reduced interference effect as attributable to a reduction in "motor-component antagonism" when responses are of different "response colasses". Morton (1969), noting stimuli with shared, but incongruous, meaning interfere with responding, suggested that input into the logogen system from any source activated associated logogens. Similarly, Posner (1978) described activation of associated pathways.

Most theoretical and experimental literature regarding the Stroop effects has dealt with probable sources and mechanisms of interference. Few published reports have described probable mechanisms involved in over-coming the interference and emitting the "task appropriate"response. Klein (1964) described "re-stimulation" of the color information (i.e., re-processing information from color aspect) as a possible mechanism for increasing the activation level of the color-naming response. He did not, however,explain how the "attensive power" of the word-reading response, assumed to dominate color-naming responses, was reduced or controlled during the "re-stimulation" process. Dyer (1973) and Posner (1978) have suggested that in addition to being a more rapid response, word activation has a relatively short time course. In this model, interference would not be "over-come", but "waited out".

As described above, explanations of the reduced interference effect obtained in Reverse and Unrelated Word Interference conditions have also been both active (e.g., selective attention to word) and passive (e.g. activation of responses varying in number of associated pathways, or differing with respect to rate or time course). Jensen and Rohwer (1966) and Dyer (1973) have also suggested that subjects may learn to attend response availability, or response set cues, as a means of reducing interference effects. Data provided by the pre-exposure studies described by Dyer (1973) appeared to support differences in time course for word-reading and color-naming response activities; however, the evidence of reduced interference in conditions which might permit selective attention to stimulus aspect, or to response set, has supported use of active selection mechanisms when available.

Reduction in response times on interference conditions over trials (Stroop, 1935) and in derived score interference effects with repeated measures (Jensen, 1965) also suggest that subjects may "learn" methods of attending to stimuli, or inhibiting responses which facilitate responding in interference conditions.

In the present context, experimental hypotheses regarding the Stroop effects were formulated as tests of the occurrence of previously reported Condition, Trial, and Condition by Trial effects on response time measures and derived scores. The main prediction with respect to Stroop effects was that they would be obtained in the present experimental design in accord with previous results, despite procedural differences in sampling and presentation methods. Experimental effects: interference in Reverse Stroop Condition,

interference in Unrelated Word Condition, and response times to congruent color/word stimulus items had not been previously tested in connection with between groups differences. The predicted orders of magnitude for response times and for interference effects were based on previous evidence from studies regarding the Stroop Tasks. Alternate hypotheses regarding the sources or mechanisms of the Stroop effects were not tested; however, they were discussed in relation to age differential effects in Stroop Task performance.

Age Differences in Stroop Effects

Adult age differences in performance on Stroop Tasks have been reported by Comalli, Wapner, and Werner (1962) and by Schonfield and Trueman (1974). Both studies reported differential interference effects, with aged subjects demonstrating longer response times on the Stroop Interference Condition relative to those of younger subjects. Age differences on the interference conditions were reported to be disproportionately great, relative to differences on non-interference, or reduced interference conditions.

Comalli, et al. (1962) interpreted the performance of elderly subjects as evidence of loss of differentiation and hierarchic integration of function. Assuming performance on the Stroop Interference Task required selective attention to color aspect of the stimulus, and differentiation of reading and naming responses, Comalli, et al. suggested that loss of differentiation and hierarchic integration was reflected in slower response times on that condition.

Comalli, et al. reported results of a comprehensive life-span study, including subjects aged seven to eighty years of age. The

data appeared to support the predictions of differential interference effects for elderly adults; however, there were several features of their sampling, testing and contrast procedures which may have biased the results in this direction. Subjects of the younger age groups (aged seven to forty-five) were all obtained from educational settings (e.g., elementary, high school, university and community colleges). Subjects in the oldest age group (aged sixty-five to eighty) were described as members of a community "Old Age Club". Education, usual occupation, vocabulary, and other variables which may have discriminated between adult age samples obtained from these sources have not been experimentally defined in relation to performance on Stroop Tasks; however, to the extent that Stroop Task performance may vary as a function of type or frequency of exposure to similar stimuli and responses, or as a function of adaptability to experimental task demands, differences on these variables may have contributed to between group differences in performance.

The subject groups also differed with respect to both the number of subjects in each group and within-group variability in response times. As the primary analysis of data was an Analysis of Variance on Age Groups and Conditions, the test for significance of of effects could have been biased (Boneau, 1960).

The interpretation of greater magnitude age differences in the Stroop Interference Condition as representing age differential interference effects was also questionable. Differences in mean response time between adult age groups on non-interference conditions were not tested. Greater magnitude age differences in response times would be predicted for conditions requiring longer response times

with proportional differences across interference and non-interference conditions. Although the age differential interference effect was also reported to have been supported by a non-parametric test on difference scores (i.e., C_3-C_2), the single administration procedure used has not been found to result in reliable derived scores (Jensen, 1965).

The "regression" hypothesis , considered by Comalli et al. to be of "heuristic value", has not been tested in subsequent research, and was not well supported by their results. Tasks on which performance protocols could be contrasted would be more appropriate for testing the "regression" hypothesis than tasks for which only end performance measures are available.

Schonfield and Trueman (1974) reported the results of a study which contrasted adult age groups in response time to variants of the Stroop Interference Task requiring double responses. Obtained response times across conditions and groups indicated that older subjects were relatively less disadvantaged in a condition requiring the emission of color-naming responses congruent with word-reading responses, prior to emitting color-naming responses incongruent with word-reading responses. These results were interpreted as supporting the hypothesis that age differences in Stroop Interference effects were attributable to differential strength of association. Older subjects were suggested to have greater difficulty in inhibiting "strong" Stimulus - Response associations, and to be less disadvantaged when the strong association could be gotten "out of the way" first.

The results reported by Schonfield and Trueman appear to be less explicable on the basis of slowing in rate of processing, or other alternative explanations than the data reported by Comalli, et al. (1962). Although the sample selection procedures were not described in the 1974 report, Schonfield and Trueman contrasted equal numbers of subjects in each of five age groups, and all contrasts were on within-subject measures across conditions. However, the absence of either contrasts of age groups on congruent information conditions, or single aspect conditions, and the presence of residual age differences in the condtions demonstrating the least between group differences, left "proportionate" age differences in question. In addition, conditions requiring the inhibition of relatively weak (e.g., color-naming) responses were not directly tested. Each condition requiring the inhibition of word-reading responses, with the exception of the traditional Stroop Interference Condition, required inhibition of both word-reading and color-naming responses in order to make the required color-naming response. Therefore, although old subjects appeared to exhibit differentially great difficulty in inhibiting responses, the specificity of this age effect to "strong association" was not demonstrated.

Assumptions made by Comalli, et al. (1962) regarding mechanisms of reducing Stroop Interference effects (i.e., selective attention to stimulus attribute, maintenance of a specified response set) have not been well supported by subsequent research regarding the Stroop effect (e.g., Treisman and Fearnley, 1969; Klein, 1964). However, the Unrelated Word Interference effect and the Reverse Interference

effect may provide better tests of their hypotheses than did the usual Stroop Interference Task.

Similarly, the assumptions regarding Stroop Interference implicit in the theoretical formulation of Schonfield and Trueman (1974) have been questioned. The assumptions that relative "strength of association" is a determining factor in the magnitude of Stroop Interference effects, and that overcoming interference requires inhibition of the word-reading response habit, have not been universally supported by reaserch with Stroop effects (e.g., Treisman and Fearnley, 1969; Jensen, 1965; Dyer, 1973). Although it appears plausible that older adults would have stronger word-reading habits than younger adults due to extended experience with reading, it would be more likely that word-reading response times would reach a asymptote by maturity. Age-related increases in interference effects have not been supported by the developmental research reported with children (Comalli, et al.,1962; Jensen and Rohwer, 1966).

Alternate interpretations of the obtained age differential interference effect on the Stroop and similar information processing tasks include differences in rate of processing, and differences in adaptability to experimental task demands. Kinsborne argued that apparent age differences in interference were attributable to the generally slower rate of processing of old adults. As noted above, the results reported by Comalli et al. (1962) could be interpreted in this manner. The results reported by Schonfield and Trueman (1974) do not appear explicable on the basis of general slowing; however, "proportional" age differences were not experimentally described in their study.

Fozard, et al. (1977) suggested that the age differences results obtained with Stroop Tasks might be attributable to differences between age groups in adaptability. Although the differences between double response times reported in the Schonfield and Trueman study (1974) do not appear explicable on this basis, both their study and that reported by Comalli et al. (1962) involved contrasts between age groups on single measures. Age differences in "practice effects", reflecting differences in adaptation to the task were not examined in either study.

Experimental Hypotheses:

I. Hypothesis regarding Stroop Effects

The main hypothesis regarding Stroop Effects was that the usual Stroop effects would occur. These effects were expected to be demonstrated by

A. Differences between conditions in response times and in derived interference scores. Differences predicted between conditions were:

(1) Reading response times shorter than naming response times across interference and non-interference conditions.

(2) Response times to conditions presenting single or congruent stimulus attributes (i.e., non-interference) shorter than response times to conditions presenting incongruent stimulus attributes.

(3) Response times for interference conditions in which the attribute incongruent with the required response is Color (i.e., Reverse Interference Condition) shorter than response times for conditions in which the incongruent attribute is Verb (i.e., Unrelated Word Interference Condition) shorter than response times for conditions in which the incongruent attribute is Color Word of the same response class as the required response.
The same relation was predicted for derived interference scores: Stroop Interference effect greater than Unrelated Word Interference effect greater than Reverse Interference effect.

B. Differences in response times for conditions with repeated measures across trials. Differences predicted across trials were:

(1) Response times for conditions decreasing across trials (i.e., "practice effects")

(2) Interference conditions demonstrating greater "practice effects" than non-interference conditions.

II. Hypotheses regarding Age Differential Stroop Effects

The main hypothesis regarding age differential Stroop Effects was that age differential Stroop Effects would occur. These effects were expected to be demonstrated in "disproportionately " greater age difference in reponse times for interference conditions, and in differences between age groups on derived interference scores (i.e., differences between conditions indexing interference effects). These age difference effects were predicted to occur by

A. Differential association strength. Older adults having relatively greater difficulty inhibiting strong associations (i.e. over-learned reading habit) due to acquired greater association strength. Differences predicted between age groups were:

(1) Older adults demonstrating relatively longer response times on interference conditions requiring the inhibition of Word - reading associations (i.e., Stroop Interference Condition, and Unrelated Word Interference Condition, and larger magnitude derived scores indexing interference effects: Stroop Interference and Unrelated Word Interference effects.

(2) Older adults demonstrating relatively greater word-reading association strengths relative to color-naming association strengths (i.e., smaller word-reading / color-naming response time ratio in non-interference conditions).

(3) Differences between age groups in response times for non-interference conditions, and on response time for Reverse Interference Condition, were predicted to be proportionate across conditions.

B. Differential efficiency or effectiveness of "selector mechanisms". Aged adults disadvantaged in performance of tasks requiring selective attention to stimulus aspect, selective attention to response class, or selection and inhibition of task inappropriate response, due to loss of efficiency or effectiveness of "selector mechanisms". Differences predicted between age groups were:

(1) Aged adults demonstrating longer response times on conditions presenting more than one stimulus attribute, with attributes not congruent (i.e., Stroop Interference Condition, Unrelated Word Condition, Reverse Stroop Interference Condition), relative to response times on non-interference conditions, and age differences on non-interference conditions. Larger magnitude derived scores indexing interference effects: Stroop Interference, Unrelated Word Interference, and Reverse Interference effects.

Other explanations of the greater mean response times of elderly adults in the Stroop Interference Condition which were tested in the experimental design included age differences in general rate of processing, age differences in adaptation to experimental task, and age differences interactions with sex differences on Stroop performance.

The possibility that age differential in performance of Stroop Tasks might be attributable to general slowing in rate of processing was examined by testing for differential interference effects. It was assumed that if older adults demonstrated longer response times across interference and non-interference conditions, but age

age differences were proportional across conditions, group differences in response times and derived scores could be attributable to generally slower processing of older adults.

Potential sex differences were controlled by including the same numbers of males and females in each of the three age groups. This also provided a means for determining the significance of Age Groups X Sex interactions on task performance.

Control Measures

Subject selection and matching criteria were included in the design of the study in order to reduce the number of variables on which age groups differed. Selection and matching procedures for subject samples, described in the Methods Section, were designed to reduce differences between age groups in both nature of prior experience with associations involved in the Stroop Tasks, and in variation between age groups attributable to differences in verbal intelligence, sensory impairment, or infirmity. Age group differences of interest were differences between adult age groups attributable to differences in length of experience with words and colors, and "normal aging changes" in psychophysiological status.

METHOD

Research Design:

A Four Way: Age Groups (3 levels) X Sex (2 levels) X Condition (6 levels) X Trials (4 levels) design was followed. Subjects were nexted in Age Group and Sex, and repeated measures were made on each of six Conditions across four Trials. The six experimental Conditions were:

C_1 Read words on Card 1, Color words printed in black ink.

C_2 Name colors on Card 2, Color patches.

C_3 Name ink colors on Card 3, Color name words printed in incongruent ink color.

C_5 Name ink colors on Card 5, Verbs printed in colored ink.

C_6 Read words on Card 3, Color name words printed in incongruent ink color.

All subjects participated in each of the six Conditions, four Trials in each of the conditions, for a total of twenty-four measures on each subject. Order of Condition was fixed across the four trials, with Conditions presented in the order: C_1, C_5,C_4, C_3, C_2, C_6, for all subjects.

Subjects:

Sixteen subjects in each of three adult Age Groups were selected to participate in the study. All subjects were unpaid volunteers, selected from the population of active community-living adults, on the basis of the following selection and matching criteria:

Selection Criteria: (1) Willingness to volunteer to participate in psychological research; (2) Chronological age within one of three defined age agroups: Young adult(15-25years old), Middle-aged adult(35-50 years old), Old adult(65-80 years old); (3) Absence of demonstrated or self-reported sensory deficit (e.g., color blindness, uncorrected visual or auditory impairment); (4) Performance score on modified version of Quick Word Test of above 70%.

Matching Criteria: (1) Education level, based on years of education; (2) Usual occupation, or pre-retirement occupation, categorized: (a) Skilled trade; (b) Clerical; (c) Professional.

Subjects for the three Age Groups were solicited from: (1) University non-academic staff; (2) Provincial Government office staff; (3) Volunteer staff of a community Senior Drop-in Center; and (4) Members of the Society for the Retired and Semi-Retired.

Prospective subjects were solicited directly, and selection of subjects was made from among volunteers. Subjects who failed to satisfy selection criteria (e.g., were later identified as having deficient color-vision, or obtained a score of less than 70% on the modified Quick Word Test) were replaced with subjects from the same pool of volunteers.

On the basis of selection criteria, seven subjects were discarded with replacement. Two subjects were replaced due to deficient color vision: one subject from the Young sample (A_1); one subject from the Old sample (A_3). Four subjects were replaced due to performance score below 70% on the vocabulary test: one subject

from A_1 ; two subjects from the A_2 group ; and one subject from the A_3 group. One subject, from the A_3 group, was replaced due to refusal to complete the experimental procedure.

Matching of Age Group samples was accomplished as nearly as possible by solicitation and selection procedures. The three experimental groups were described on the basis of age, years of education, occupation, and % score on the modified Quick Word Test.

Age Group A_1: Experimental Subjects ranged in age from sixteen to twenty-five years, $\bar{X}$ age = 22.13. Twelve of the Subjects in A_1 had completed high school, two had completed a four year university program, and two had completed grade eleven. Eight of the subjects in this sample were employed in Skilled Trades (e.g., printer, photographer, machine shop worker, elctrician), five were employed in clerical positions (e.g., typist, book-keeper, order clerk), and two were employed in professions requiring university training (e.g., nurse, elementary school teacher). Scores on the modified version of the Quick Word Test, after replacing one subject, ranged from 80% - 96%, $\bar{X}$ = 81.81, s.d. = 8.52.

Age Group A_2: Experimental Subjects ranged in age from thirty-five to fifty years, $\bar{X}$ age = 41.0. Eleven Subjects in A_2 had completed grade twelve, one had completed grade thirteen, and two had completed a four year university program. Six of the Subjects in A_2 were in Skilled trades (e.g., electrician, machine operator,draftsman, layout artist), seven Subjects were in clerical positions(e.g., receptionist, secretary, file clerk, book-keeper), and two were employed in professions requiring university training (e.g., nurse, business).

and one was working as a full-time volunteer in a Senior Drop-In Center. Scores on the modified version of the Quick Word Test, after replacing two Subjects, ranged from 70% - 98%, $\overline{X}$ = 85.25, s.d. = 7.69.

Age Group A_3: Experimental Subjects ranged in age from sixty-four to seventy-eight years, $\overline{X}$ age = 71.16. Twelve Subjects in A_3 had completed grade twelve, one Subject had completed grade eleven, one Subject had completed two years of college, and two Subjects had completed a four year university program. Only one Subject in A_3 was currently employed full-time. The other fifteen subjects had retired from the following occupations: two from teaching school, eight from Skilled trades (e.g., barber, seamstress, plumber, electrician), five from clerical positions (e.g., typist, bank teller, insurance clerk, secretary). Eight of the Subjects in A_3 were working in a voluntary capacity at a local Senior Drop-in Center, as excorts for residents in a local nursing home, or delivering Meals-On-Wheels. Scores on the modified version of the Quick Word Test ranged from 70% - 96%, $\overline{X}$ = 82%, s.d. = 8.33.

Materials:

A. Quick Word Test. A modified version of the Quick Word Test: level 1 - Form Bm (Borgatta and Corsini, 1957) was developed for experimental use. The first fifty items of the published form were typed in upper case letters, with response choices typed to the side of each item. Responses were selected and under-lined on the test form. A copy of the modified version of the Quick Word Test is included in Appendix B.

B. Stimulus Cards. Five stimulus cards were designed for use in six experimental Conditions. Each card measured 28 cm X 36 cm, white poster board. Stimulus items on each card were positioned 2.5 cm apart, with a 20 item single row on Practice side, and five rows of 10 items each on the Test side. Each stimulus item measured .5 cm in height, X between 1.5 cm and 3 cm in length (color-only stimuli measured .5 cm X 2.5 cm; Color-words ranged in length from 1.5 cm for word RED, to 3 mc for word YELLOW). All word items were hand printed in upper case letters, using a tracing stencil to promote uniformity and clarity of letters. Pens for color stimuli were Stabilo fine point nylon-tip, color numbers: Yellow, 68/44; Brown, 68/75; Green, 68/36; Blue, 68/50. All cards were laminated. Words and colors on each card were positioned such that no item occurred twice in succession, and care was exercised to avoid patterns of color sequence and relations between sequential items. A detailed description of the stimulus cards is included in Appendix B.

Dependent Measures:

A. Modified Quick Word Test was scored as per cent correct responses out of a possible fifty correct.

B. Experimental Conditions. All measures on the six experimental Conditions were time scores. Time required for responses to fifty Test items on each Card were measured by a hand-held, manually operated Cronus Single-Event digital stop-watch. Times, recorded in seconds and hundredths of seconds, were recorded for each of six Conditions, across four trials. In addition, derived scores, calculated as the difference between response times for Conditions and as

ratios of response times, were used as the basis of comparisons between Age Groups.

Procedure:

A. Subject Selection. Individuals of three general age groups were approached regarding suitability and willingness to participate in the planned study. All subjects were solicited from the community; however, in order to obtain samples from different age groups matching as nearly as possible on other variables (e.g., level of education, verbal intelligence as measured by vocabulary test, general health, usual occupation), it was necessary to approach several community groups.

Subjects for the two youngest Age Groups, A_1 and A_2, were solicited from two sources: (1) Non-academic staff on the university campus, and (2) Office staff of a government office. Subjects obtained from these two sources represented both "white collar" and "blue collar" skilled workers, with between eleven and fifteen years of education. Age Groups A_1, X years of education = 12.8; A_2, X years of education = 13.2.

Subjects for the oldest Age Group, A_3, were solicited from three sources: (1) Individuals over the age of sixty-five who had previously participated in Age Differences research, unrelated to the present study; (2) Individuals who as members of the Society for the Retired and Semi-Retired had indicated an interest in participating in psychological research; (3) Volunteer Staff of a local community Senior Drop-in Center. Subjects obtained from these groups reported pre-retirement occupations in both "blue

collar" and "white collar" skilled occupations, and education levels ranging from 11 to 15 years of formal education, X = 13.5 years.

Subjects of all three Age Groups were in self-reported good health, and active in the community. Subjects having agreed to participate in the study, and meeting other selection criteria, were administered the modified version of the Quick Word Test. On the basis of these scores, four subjects were replaced. Subjects were asked whether they experienced any difficulty in discriminating colors, prior to testing; however, two subjects were unable to discriminate the color stimuli on experimental tasks, and were discarded with replacement. Each of the three experimental Age Groups consisted of sixteen Subjects, eight males and eight females, for a total of forty-eight subjects.

B. Experimental Procedure. All Subjects participating in the study were tested individually by the following procedure:

1. Introduction. Subjects were told that the tasks to be performed were of an experimental nature, and that the relation between performance on the tasks and either general or specific intelligence, or any personality variable, was undefined. The task was described as an information processing task. Subjects were informed that results of the vocabulary test were to be used to match subject Groups of different ages. Subjects were shown the five stimulus cards, and told that they would be asked to either Read the word or Name the color on each Test Condition. They were informed that a 10-item practice trial would precede each timed trial, and instructed to respond as quickly and accurately as possible on each timed trial.

Card one was then placed on the table, practice side up, and facing the Subject. The Subject was asked if the items could be seen and discriminated. When the answer was affirmative, the Subject was told that each card would be placed in the same position and orientation, and that the Subject should refrain from moving the card or shifting his own position to view the card from an angle. Subjects were also instructed not to squint or otherwise attempt to alter their view of the stimuli, and told that the Experimenter would be monitoring for both errors in responding, and failure to follow instructions.

2. Conduct of the experiment. Each of the five cards was presented to the Subject in the Order of Conditions: C_1, C_5, C_4, C_3, C_2, C_6 , across four trials. (Conditions were as described on page 86). A practice trial preceeded timed trials on each Condition. Instructions were given to Read the words, or Name the color of ink, as each card was placed in position. If the Subject erred in responding on the practice trial (e.g., read words when instruction was to name colors) he was interrupted with repetition of instructions. Errors in responding in practice trial on any item were pointed out, to emphasize the importance of both speed and accuracy on timed trials.

The six experimental Conditions included three Naming and three Reading Conditions. The Order of presentation required responses in the order: Read, Name, Read, Name, Name, Read. Three of the Conditions represented Interference Conditions, and three were Non-interference Conditions. The Order of presentation resulted in alternation between Interference and Non-interference Conditions.

Subjects were permitted to rest between conditions, or between trials, and were told after each trial of six conditions how many trials remained.

At the conclusion of the experimental session, each Subject was informed of the generality of findings with Stroop-related tasks. Subjects were assured that difficulty experienced with interference conditions is usual. Current theory regarding the nature of the Interference effect was explained. Subjects were encouraged to ask questions regarding the possible sources of individual and Age Group differences in the magnitude of the Interference effect.

The total experimental time required varied across Subjects within Age Groups, ranging from 40 minutes to 65 minutes. Between Groups, A_1 and A_3 Subjects required slightly longer times, principally because Subjects in these Age Groups asked more questions at the conclusion of the session.

Data Analysis:

The initial analysis was a planned Four Way Analysis of Variance: Subjects (8) nested in Sex (2) and Age Groups (3), crossed with Conditions (6) and Trials (4). It was assumed that results of this analysis indicated the significance of factors: Age Groups, Sex, Condition, and Trial, and the significance of two, three, and four-way interactions of these factors. The results of this analysis were interpreted as evidence regarding the probability that usual differences between conditions, across trials, and differences between conditions across trials, had been obtained. Evidence was also

provided regarding the occurrence of age group differences in response times across Conditions (i.e., age differential Stroop performance) and across Trials (i.e., age differential "practice effects"). However, neither the direction of main effects, nor the nature of interactions were revealed by this analysis.

Duncan's Multiple Range Test (Edwards, 1972) on data means, averaged over Subjects, Sex and Trials within Age Groups for each Condition, indicated conditions which differed significantly in mean response time, order of response times for conditions, and conditions on which age groups were significantly different. These data provided further evidence regarding the hypothesized Stroop condition differences, specifically with respect to predicted differences in reading versus naming, interference versus non-interference, and within interference conditions. The between group differences across conditions also provided further evidence regarding the nature of age differences in response times across Stroop conditions. Ratios of mean response times for age groups across conditions (i.e., A_3/A_1, A_3/A_2, A_2/A_1) were calculated to examine the "proportionality" versus "disproportionality" of age differences across conditions.

More direct tests of the experimental hypotheses regarding the nature of the age differential interference effect were made by independent analyses of derived scores. Within subject difference between response times on Condition $_3$ and Condition$_2$ (i.e., C_3-C_2) has been described as an index of the Stroop Interference effect of words on color-naming. Within subject difference between response times on Condition$_5$ and Condition$_2$ (i.e., C_5-C_2) has been described

as an index of reading interference, effect of non-color words on color-naming. Within subject difference between response times on Condition 6 and Condition 4 (i.e., C_6-C_4) has been described as an index of Reverse Interference, effect of color on word-reading. Independent Analyses of Variance and Scheffés test for significant differences in contrasts on sums were conducted for each of the difference scores C_3-C_2, C_5-C_2 and C_6-C_4 (Edwards, 1972). Data for the analyses of variance were derived from within-subject difference scores, averaged over Sex and Trials. Scheffés contrasts were conducted on Age Group sums of difference scores, using the Mean Square within from the appropriate ANOVA as the variance term. Scheffés tests were made as contrasts of the three age groups: A_1 vs. A_2; A_1 vs. A_3; A_2 vs. A_3; and A_1 + A_2 vs. A_3.

Analysis of Variance and Scheffés Test were also conducted on the ratio score C_1/C_2, contrasting age groups on the derived score which has been described as indexing the relative strengths of word-reading and color-naming responses (Jensen and Rohwer, 1966).

The results of these analyses were used as the basis for interpretations regarding hypothesized sources of age differential Stroop Interference (i.e., differential association strength, differential selective mechanisms).

A Trend Analysis was conducted to determine the significance of linear and quadratic trends in the data across trials, and in interaction with Sex and Age Groups. The results of this analysis were discussed in connection with possible "practice effects", and differences between Age Groups and Sexes in "practice effects" over trials.

As significant differences were predicted on specific tests and specified direction, a per comparison error rate was used for all contrasts.

Rank Order correlation coefficients were calculated, contrasting chronological age and six experimental measures: performance score on the modified version of Quick Word Test, Speed (C_1), Color-difficulty (C_1/C_2), Stroop Interference (C_3-C_2), Unrelated Word Interference (C_5-C_2), and Reverse Interference (C_6-C_4). Correlations were calculated pair-wise, between data points averaged over four trials for each of 48 subjects. The obtained correlations were compared with the intercorrelations of derived scores reported by Jensen(1965), and discussed in relation to age differences on experimental effects.

RESULTS

The results of the Four Way Analysis of Variance: Subjects nested in Age Group and Sex, and crossed with Condition and Trial, are summarized in Table 1, Appendix C. The significant main effects of this anaylsis were: Age Group, $F_{(2,45)} = 7.96$, $p < .01$; Condition, $F_{(5,210)} = 656.02$, $p < .01$; and Trial, $F_{(3,126)} = 83.96$, $p < .01$. The variable Sex, was not significant in this analysis, $F_{(1,42)} < 1.00$.

The interactions: Age Groups X Conditions, $F_{(10,210)} = 7.71$, $p < .01$; Condition X Trial, $F_{(15,630)} = 13.71$, $p < .01$; Age Groups X Trial, $F_{(6,126)} = 2,86$, $p < .05$; and Sex X Trial, $F_{(3,126)} = 4.64$, $p < .01$, were also significant. Interactions: Age Group X Sex, Sex X Condition, and higher order interactions were non-significant.

These results were in accord with predictions regarding the occurrence of Condition, Trial and Condition X Trial effects with the experimental materials and procedures, and suggested that the hypothesized Stroop effects were obtained. They also indicated that the Age Groups differed significantly across Conditions, and across Trials, in accord with predictions of age differential Stroop effects. However, neither order of response times across conditions, nature of differences between trials, differences betweeen age groups, nor nature of interactions was revealed by this analysis.

Duncan's Multiple Range Test procedure was used to examine between age group differences across the six conditions, and the differences in response time on the six conditions across the three age groups. The comparison, shown in Table 2, Appendix C, was between eighteen Age Group X Condition means, averaged over subjects, sex and trials.

This contrast, also illustrated graphically in Figure 5, Appendix C, indicated that the predicted orders of magnitude in response time of experimental conditions were obtained. Reading response times (i.e., C_1, C_4, C_6) were shorter than naming response times (C_2, C_5, C_3); response times to interference conditions (i.e., C_5, C_3) were longer than response times to non-interference conditions (i.e., C_1, C_2, C_4). Within interference conditions, the Reverse Interference Condition mean response times were shorter than Unrelated Word Interference Condition mean response times, and response times for Unrelated Word Interference Condition were shorter than mean response times for Stroop Interference Condition. These relations between Conditions in mean response time held across Age Groups, with the order of magnitude: $C_1 \leq C_4 \leq C_6 < C_2 < C_5 < C_3$.

Differences between age groups were not significant for comparisons between the youngest (A_1) and the middle-aged (A_2) groups on mean response times for Conditions one through six. Mean response times for the oldest group (A_3) were significantly different ($p < .01$) from those of A_1, and A_2 on Conditions three, five, and six (i.e., the interference conditions) but not significantly different on Conditions one, two or four (i.e., the non-interference conditions). Differences between Conditions one and four were not significantly different within or between age groups. Mean response time for Condition six (i.e., Reverse Interference Condition), was significantly different from Conditions one and four (i.e., non-interference reading condition) only for Group A_3. These results indicated that age group differences obtained in the study were probably related to late age changes, and were possibly specific to the interference condition.

Calculation of the ratios of mean response times for age groups (i.e., A_3/A_1, A_3/A_2, A_2/A_1) across the six conditions, indicated that the response times of older subjects on interference conditions were disproportionately longer, relative to age differences on non-interference conditions. These ratios are shown in Table 3, Appendix A.

In order to test more directly for significance of age group differences in the Stroop Factors described by Jensen (1965), separate analyses were conducted on each of the derived interference scores (i.e., C_3-C_2, C_5-C_2, C_6-C_4), and on the derived color-difficulty score (i.e., C_1/C_2 ratio) which was also interpreted as indexing relative association strength of word-reading and color-naming responses. Analyses on each of these derived scores were within and between groups analyses of variance, with derived scores calculated for each subject, averaged over four trials. Scheffes' test for significant differences between sums was made comparing the three age groups on each of the derived scores.

The results of these analyses, summarized on Tables 4, 5, 6 and 7, Appendix C, indicated that there were significant differences on the derived interference scores: Stroop Interference, $F_{(2,45)} = 14.84$, $p < .01$, significant at $\alpha = .01$ for Contrasts A_1 vs. A_3, A_2 vs. A_3, and $A_1 + A_2$ vs. A_3; Unrelated Word Interference, $F_{(2,45)} = 5.95$, $p < .01$, significant at $\alpha = .01$ for Contrasts A_1 vs. A_3 and A_2 vs. A_3; and Reverse Interference, $F_{2,45)} = 7.79$, $p < .01$, significant at $\alpha = .01$ for Contrasts A_1 vs. A_3, A_2 vs A_3, and A_3 vs. $A_2 + A_1$. The differences between A_1 and A_2 on derived interference scores, and between all age groups on derived ratio scores C_1/C_2 were non-significant.

The Speed Factor, indexed by response times on Condition one (Jensen, 1965), was evaluated on the basis of results obtained in Duncan's Multiple Range Test. Failure to obtain significance in contrasts of the three age groups on Condition one (i.e., reading color words in black ink) or Condition four (i.e., reading color words printed in congruent color ink) was interpreted as no evidence of between group differences on the Speed Factor.

The results of the analyses of derived scores indexing interference effects were interpreted as evidence that differences between the age groups on the Interference Factor were significant. As all three derived interference scores (i.e., indices of Stroop Interference, Unrelated Word Interference, and Reverse Interference) indicated greater interference effects for the oldest age group (A_3), and the ratios of response times (C_1/C_2) indexing the color-difficulty factor and relative association strengths were not significantly different across age groups, the hypothesis attributing age differences to differences in function of selector mechanisms was considered supported. The hypothesis attributing age differences to acquired differential association strengths was not supported by these results.

The significant Trials effect, and significant Age Group, Condition and Sex interactions with Trials, obtained in the Four Way Analysis of Variance, indicated that "practice effects" , differentiating between sexes, groups and conditions might have occurred over trials. A Trend Analysis, summarized in Table 8, was conducted to determine the significance of linear and quadratic trends in the data across Trials, and in interaction with sex and age differences.

Although both linear, $F_{(1,5)} = 236.26$, $p < .01$, and quadratic $F_{(1,5)} = 9.6$, $p < .01$, were significant, only the interactions Sex X Linear, $F_{(1,5)} = 9.82$, $p < .01$ and Age Group X Linear, $F_{(1,5)} = 4.74$, $p < .05$, were significant interactions. The Age Groups X Sex X Linear and interaction between Sex, Age Groups and Quadratic trend were all non-significant.

As illustrated in Figure 6, Appendix A, the mean response times (averaged over groups and conditions) decreased across trials, with the greatest decrease between Trials one and three, and a smaller difference between Trials three and four. This relation between response time and trials was consistent with the results regarding reliability of response time measures reported by Jensen (1965) and "learning effects" reported by Stroop (1935). The Age Groups X Trials interaction is graphed in Figure 7, Appendix A, mean response times for Age Groups (averaged over subjects and conditions) across Trials. Old (A_3) and Middle-aged (A_2) subjects demonstrated roughly parallel reductions in response times across Trials 2 through 4; however, the Old Age Group reduction in mean response time was relatively greater between Trials 1 and 2. The mean response times of the Young Age Group (A_1) were shorter than those of the older groups for Trials 1 through 3; however, the mean response times of this group demonstrated smaller reductions between Trials 3 and 4. The mean response time of the youngest group was slightly longer on Trial four than that of the middle-aged group.

The Sex X Trials interaction is presented graphically in Figure 8, with mean response times of the two sexes(averaged over age groups and conditions) contrasted across Trials. The relation between these

functions indicated that mean response time of male subjects were initially longer than those of female subjects; however, reduction in mean response time was greater for males between Trials 1 and 3, with the result that mean response time for the two sexes were equivalent on Trials 3 and 4. Although this relation between Sex and "practice effect" appears quite clear, Figure 9, illustrating the relation between Sex, Age Groups and Trials, demonstrates that the pattern of differences between the mean response times of the two sexes is not the same across age groups. The Age Group X Sex X Trials interaction was not a significant effect in the Four Way Analysis of Variance; however, as can be seen Figure 9, male response times and female response times of the youngest age group most closely approximated the Sex differences X Trial relation illustrated in Figure 8. Mean response time of middle-aged males were longer than thos of middle-aged females, however, the mean response times of the two sexes in this age group maintained roughly the same relation across Trials 1 through 3, with male mean response times slightly increasing on trial four. For the oldest subjects, sex differences were in the opposite direction, with mean response time of the females slightly longer than those of males on Trials one and two, and smaller practice effects for females across the four trials.

Although male mean response times were initially longer (averaged across age groups), this was not manifested over all four trials, nor were sex differences in this direction for the oldest age group. Non-significance of the main effect Sex in the initial Four Way analysis, and absence of significant interactions between Sex and

Conditions, Sex and Age Groups and other interactions, were interpreted as indicating that sex differences were probably not a critical factor in the present study.

The nature of the Trials X Condition interaction, significant in the Four Way Analysis of Variance, is described in Figure 10, Mean response times for each of six condition, averaged over groups, were calculated across four trials. From the relation between conditions and trials, it can be seen that conditions differ with respect to the magnitude of the reduction in response time across trials. Condition three reflected the greatest reduction in mean response time, with an average 8.08 seconds difference in mean response time between Trials 1 and 4. Condition five reflected an appreciable reduction in response time across trials also, with 3.76 seconds difference between Trials 1 and 4. The differences in response times across Trials for the other four conditions were between .86 seconds and 2.15 seconds. The greatest difference in mean response times for all conditions was between Trial one and Trial three, with very small reductions in response time averages between Trials three and four.

The interaction effect was interpreted as supporting the hypothesis regarding interference effects greater effect of practice, and was in accord with previously reported effects of repeated measures on response times for interference versus non-interference conditions (Stroop, 1935).

Evidence of significant Trials effects, and of an interaction between the Linear trend in the data and Age Groups, indicated a possible source of bias in the Four Way Analysis. As the Age Groups X

Maintained across trials. The Age Group X Trials interaction appeared to result in an increase, rather than a decrease in the differences between age groups on interference effects.

The form of the interaction between age groups and interference scores across trials are presented graphically in Figure 11, representing difference scores averaged over subjects in each age group, across four trials, and in Figure 12, representing mean response times for each of the three age groups, averaged over interference versus non-interference conditions,across four trials.

A correlation matrix, based on the Rank Order correlations of mean scores, calculated between each pair of data means on six measures and age for 48 subjects, is presented in Table 12.

From this Table it can be seen that the correlations between the modified Quick Word Test and experimetnal measures were small and non-significant, except in the case of the positive correlation between vocabulary score and the interference score C_5-C_2 (i.e., Unrelated Word Interference) , r_{47}= .304,$p<.05$. This indicated that higher scores in the range 70-96% on the modified version of the Quick Word Test may be related to greater interference from non-color words, and have little relation to Speed, Color-difficulty, or other Interference factors. However, it should be noted that subjects were selected on the basis of vocabulary test score above 70%; therefore, correlation between this score and other measures would not be expected to be high.

The correlation between Color-difficulty scores (i.e., C_I/C_2) and the other factors was small and non-significant, as was expected on the basis of Jensen's (1965) factor analysis. Of

Trials interaction had been demonstrated to be significant, it was considered possible that the correlation between repeated measures could be unequal across the three Age Groups. Edwards (1972) suggested that the appropriate safe-guard against a liberal bias under these conditons was the use of the Guisser-Greenhouse correction factor. The recommended procedure reduces the evaluative degrees of freedom for obtained F by the factor: $(t-1)\left(\frac{\text{df between}}{\text{df within}}\right)$. In the present case, the Trials X Age Group and Condition X Age Group interaction Fs were evaluated with the corrected degrees of freedom, for more conservative tests of significance. Using this procedure, the interaction Age Group X Condition, $F(10,42) = 7.71$, $p < .01$, and Age Group X Trials, $F(6,42) = 2.86$, $p < .05$ were still significant at the previously determined levels.

It was also considered possible that the significant differences obtained in between group contrasts on difference and ratio scores might be due to the greater magnitude of differences in response time on the first and second trials. This appeared possible due to the above noted greater reduction between Trial 1 and Trial 2 for the oldest age group than for the two younger age groups.

In order to test this possibility, the analyses on derived scores were repeated, using Trial 4 data only. The summaries of the analyses and contrasts on the group sums for Trial 4 derived scores are presented in Tables 9, 10, and 11. As can be seen from a comparison of these Tables with the results of analyses on data averaged over four trials presented in Tables 4, 5, and 6, there was no indication that the between group differences were reduced over trials. Interaction between age groups and magnitudes of interference effects were

particular note, however, was the small correlation between Age and Color-difficulty scores in this study, $r_{47}=-.104$, n.s. As this score has also been described as indexing relative association strengths of reading and color naming responses, the low correlation is in accord with non-significant differences between the age groups in ratio C_1/C_2 reported above.

Reading speed (C_1) was significantly correlated with Interference as measured by C_3-C_2 difference scores, $r_{47}=.374$, $p<.01$. This result did not concur with Jensen's reported relation between Speed and Interference factors (Jensen, 1965). A partial explanation of the difference between results may be in the correlation between Reading Speed and Age ($r_{47}=.279$), which approached significance ($p<.10$) ($p<.10$). The data used in Jensen's study was obtained from subjects more homogeneous in age. It is possible that the relation between Reading Speed and Interference in the present study was due to common variance attributable to the Age factor.

Age was significantly correlated with the Interference factor, $r_{47}=.540$, $p<.01$, and with interference scores measured by C_5-C_2, $r_{47}=.366$, $p<.01$, and by C_6-C_4, $r_{47}=.421$, $p<.01$. In all cases, the correlations were positive, indicating greater interference with increased age.

The relation between the Interference factor measured by the difference score C_3-C_2 and difference scores C_5-C_2 and C_6-C_4 had not previously been reported. Based on the data from the present study, the correlation between interference obtained with unrelated words and the usual Stroop interference was non-significant, $r_{47}=-.189$. However, the correlation between Stroop interference measure and

Reverse Interference (C_6-C_4) was significant, r_{47}=.527, $p<.01$. The observed relation between Stroop and Reverse Interference could be due to shared variance of both factors with the Age factor in the present study; however, it could also be due to commonalities of the interference involved in responding to C_3 and C_6 (e.g., selection of response from set of color names).

DISCUSSION

Stroop Effects:

The main hypothesis regarding Stroop effects, that usual Stroop effects would occur, was supported by the results of this study.

The predicted differences between Conditions:

IA(1) Reading response times shorter than naming response times across interference and non-interference conditions

(2) Response times to conditions presenting non-interference shorter than interference

(3) Response times for interference conditions and derived interference scores: Reverse less than Unrelated less than Stroop Interference

were supported by significant differences between conditions, demonstrated by Conditions effect in the Four Way Analysis of Variance, and by significant differences in the predicted order across conditions, demonstrated by Duncan's Multiple Range Test. The Condition effects were significant for all three age groups, and the same order of response times and derived scores were maintained across Trials.

The predicted differences in response times across Trials:

IB(1) Decreasing response times across Trials

(2) Greater "practice effects" for interference than non-interference conditions

were also supported by the data. Significant differences in

response times across trials were demonstrated by Trials effect in the Four Way Analysis of Variance, and by the significant Linear and Quadratic components in the Trend Analysis. As was seen in the graphic representation of response time means, averaged over age groups and conditions, the response times were reduced across trials, consistent with a "practice effect". The interaction between Conditions and Trials effects, with greater "practice effects" across trials for interference conditions was demonstrated by the Condition X Trials effect in the Four Way Analysis of Variance, and by the observed relations between response time means and trials. Mean response times for interference conditions showed greater reduction across trials than did mean response times for non-interference conditions.

Although there were significant interactions between Trial effects and Age groups effects, reduction in response time means and greater "practice effects" for interference condition were observed for all three age groups. The magnitude of "practice effects" across trials were in accord with Jensen's (1965) report, and supported the use of repeated measures to obtain more reliable response times and derived scores.

These results regarding differences between conditions, between trials, and between conditions across trials were interpreted as supporting the hypothesis that Stroop effects were obtained using the experimental materials and procedures.

Age Differential Stroop Effects:

The main hypothesis regarding age differences in Stroop effects, that age differental Stroop effects would occur, was supported by

experimental results. Differences between the age groups in response times across conditions were demonstrated by significant Age Group effect in the Four Way Analysis of Variance, and between conditions by the significant Age Group X Conditions interaction in this analysis.

The specificity of age differences in interference conditions was demonstrated by the contrast of mean response times of each age group for the six conditions, averaged over trials. This contrast, Duncan's Multiple Range Test, demonstrated that although mean response times of the oldest age group were longer across conditions, the differences were significant only on interference conditions. The two younger age groups did not differ significantly in mean response times across conditions.

Age group ratios on mean response times illustrated the "disproportionately" greater response times of older subjects on interference conditions. The mean response times of the middle-aged and young adult age groups were approximately equal across conditions, with response times of the middle-aged group between two per cent shorter and five per cent longer than the youngest age group across the six experimental conditions. Although the greatest difference between these two age groups was on the Stroop Interference Condition (i.e., middle-aged group mean response time was 5% longer than that of the young group on C_3), the differences in mean response time between these groups were minimal on the other two interference conditions, and on non-interference conditions. Mean response times of the oldest age group, relative to the younger age groups, were longer across conditions. However, mean response times

of older subjects were between seven and eleven per cent longer than those of younger age groups on non-interference conditions (C_1, C_2, and C_4) and were between eighteen and twenty-seven per cent longer on interference conditions (C_3, C_5, C_6). These results supported the prediction of "disproportionate" age differences in response times on interference conditions, and thereby, differential Stroop interference effects.

Age differential interference effects were also supported by the finding of significant differences between age groups on the analyses of derived difference scores indexing Stroop Interference (C_3-C_2), Unrelated Word Interference (C_5-C_2), and Reverse Interference (C_6-C_4). Scheffés Tests for differences between groups on sums demonstrated significantly greater magnitude difference scores indexing interference effects for the oldest age group, than for either of the younger age groups, on all three scores. In contrasts on data averaged over four trials, and on the difference scores derived from trial four data alone, old subject group interference score sums were greater than young and middle-aged. There were no significant differences between the two younger age groups on these measures.

The correlation data also supported greater interference effects associated with age, as the correlation between chronological age and interference scores were significant despite the absence of between group differences for subjects aged 16-25 and 35-50.

Speed and Color-difficulty factors described by Jensen (1965), and represented by the response times for reading words printed in black ink (C_1) and the ratio of word-reading/color-naming response

times (C_1/C_2), did not discriminate between the age groups. The Speed factor was tested as a source of between age groups difference in Duncan's Multiple Range test, and in correlation with age. Failure to demonstrate significant differences between groups on this factor was interpreted as additional support for the hypothesis regarding differential interference effects; however, it was an interesting finding in view of previous evidence describing generally slower responses in old age (e.g., Kinsborne, 1977; Welford, 1965). The Color-difficulty factor was tested in between groups comparisons on the C_1/C_2 ratio of response times to word-reading and color-naming non-interference conditions. Differences between age groups were not significant on either analysis of variance or Scheffe's Test on ratios calculated on the basis of four trial averages or the single measures in trial four. Failure to demonstrate significant differences between age groups on the Color-difficulty factor, and non-significant correlation between age and Color-difficulty, were interpreted as evidence regarding the nature of age differences in interference effects. In addition, absence of significant age differences on the Color-difficulty and Speed factors, indicated that the relation between these factors and Organic Brain Syndrome, reported by Bettner, Jarvik and Blum (1971), may have been specific to the pathology examined in their study.

Significant age differences in Trial effects were demonstrated in the Four Way Analysis of Variance by an Age Groups X Trials interaction, and further supported by Age Groups X linear component in Trend Analysis of the response times averaged over conditions. The nature of these interactions appeared to indicate smaller

"practice effects" for the oldest age group across four trials; however, the magnitude of reduction in response times between Trials one and two appeared to be greater for the oldest subjects. Although the early trials effect might indicate age-related difficulty in adjusting to experimental task demands, the contrasts on data obtained in Trial four only indicated that age group differences were not reduced or eliminated by repeated measures.

The results of age group contrasts on Speed, Interference and Color-difficulty factors, and on "practice effects" across Trials involving repeated measures, were interpreted as indicating the presence and nature of age differential Stroop effects. Significant differences on interference condition response times and derived score measures, without evidence of age differences on either Speed or Color-difficulty factor, were interpreted as indicating the specificity of age differences in Stroop effects. Restriction of significant differences to interference effects, and "disproportionately" longer response times on interference conditions, supported the main hypothesis of age differential Stroop Interference effects, not attributable to general slowing in rate of responding.

Lack of evidence that repeated measures across trials reduced or eliminated the age differences effect, indicated that the results obtained in this and earlier studies were probably not attributable to age differences in adaptation to task demands. Although the oldest subjects demonstrated relatively smaller "practice effects" across trials, times for all groups appeared to be approaching asymptote by Trial four.

Experimental hypotheses regarding the nature of age differences in interference effects, which were tested in the present study were:

IIA. Age differential association strength, with predicted differences between age groups:

(1) Longer response times on Stroop and Unrelated Word Interference Conditions, and greater magnitude difference scores indexing Stroop and Unrelated Word Interference for older adults.

(2) Smaller ratio word-reading/color-naming response times for older adults, indexing differential association strength

(3) Proportionate differences between age groups in response times for Reverse Stroop and non-interference conditions.

The obtained results were in accord with the prediction of age differential interference effects on Stroop and Unrelated Word Conditions; however, the age differences in ratio indexing differential assocaition strength were non-significant, and disproportionate differences in response times for Reverse Stroop Interference Condition were demonstrated.

IIB. Age differential efficiency or effectiveness of "selector mechanisms", with predicted differences between age groups:

(1) Aged adults demonstrating longer response times in Stroop Interference, Unrelated Word Interference, and Reverse Interference Conditions, and greater magnitude derived difference scores for Stroop, Unrelated, and Reverse Interference effects.

The obtained results were in accord with the prediction based on the hypothesized age differences in efficiency or effectiveness

of "selector mechanisms".

Sex Differences:

Failure to demonstrate significant differences between males and females in response times averaged over conditions and trials, and absence of significant Age Group X Sex and Sex X Condition interactions were interpreted as evidence that sex differences were not a significant source of unequal variance in the present study. As sex differences in Stroop Task performance were not being studied directly, contrasts between the sexes on Stroop factors Interference, Speed and Color-difficulty were not made.

Differences between the sexes in trials effects, evidenced by significant Trial interaction and the across age group greater "practice effects" of male subjects were not explicable within the framework of either theory regarding the Stroop Tasks, or theory regarding age differences. A possible explanation of this effect might be that male subjects were less inclined to expend effort in a task which initially appeared quite simple. After experience with the task, male subjects may have worked harder in order to perform better. It was also possible that the sex of the experimenter created different context effects for male and female subjects. These explanations can only be speculative, as neither "effort" measures nor perception of context were included in the present study.

Control Measures:

The effects of control measures involving selection and matching of subject groups could not be experimentally examined

however, the apparent reduction in age difference in response time and magnitude of interference effects in this study, relative to those reported by previous investigators (e.g., Comalli, Wapner, and Werner, 1962) would indicate that between group differences in education, occupation, and vocabulary test performance may increase age differences in Stroop Task performance.

General health, controlled in this study only by self-report, may have contributed to age differences to the extent that elderly adults more frequently evidence circulatory, sensory and other disease processes than do chronologically younger adults.

Implications of Experimental Results:

Stroop Effects

The implications of results obtained in the present study with respect to the sources and mechanisms of the Stroop effects were limited. The differences between conditions maintained across age groups, cited as evidence that Stroop effects were demonstrated, testified to the robustness and generality of relative differences in reading and naming response rates, strength of the interference effect, and the effects of changes in stimulus properties or response requirements on interference effects.

Evidence of significant age differences in interference effects, without significant differences in ratios of reading and color-naming responses, did not support differential association strength (as measured by relative response rates) as a source of increased interference. The present study, by examining the performance of adult groups only, did not provide evidence regarding the establishment of

differential association strength; however, evidence of differential interference, in the absence of differences in response rate ratios, indicated that relative reading and color-naming response rate is probably not the critical factor in determining magnitude of interference.

Age differences in interference effects, without evidence of age differences in relative rates of responding in non-interference conditions, or in Speed factor, could also be argued as contrary to the differential availability of responses or name codes explanations of Stroop Interference (e.g., Dyer, 1973; Posner, 1978). However, it should be noted that the procedures followed in the present study, involving measurement of serial verbal responses to lists of items, were not sensitive to differences in time course for covert reponses. Prior evidence of differences in time course for availability of response codes was based on response latency measures to single stimuli presented tachistoscopically.

The nature of "practice effects" over trials, and differential practice effects on interference conditions supported Jensen's (1965) arguement that reliability of Stroop effects increases with repeated measures. In the present study, use of the same five stimulus cards across four trials could have increased the magnitude of practice effects. Jensen(1965) recommended the development of a set of equivalent stimulus cards for each condition, in order to prevent learning of the pattern of responses. However, none of the six experimental conditons in the present study occured twice in succession, and there was no indication that subjects were learning the order of responses.

<u>Age Differences</u>

The obtained age difference on measures of task performance were in accord with results previously described as age differential interference effects (e.g., Comalli, Wapner, Werner, 1962; Schonfield and Trueman, 1974). The differential interference effect was in evidence across interference conditions. Differences between age groups on non-interference conditions, and on ratios of non-interference scores were small and non-significant. These results were interpreted as supporting the hypothesis of age differences attributable to differences in effeciency or effectiveness of "selector mechanisms"; however, the term "selector mechanisms" in this context is imprecise and lacking in experimental definition.

Age Groups in the present study demonstrated similarities in direction of response to change in stimulus properties and response requirements, which may indicate that the same operations were performed by all subjects. If response times in the Reverse Stroop Interference condition were shorter than response times in Unrelated Word and Stroop Interference conditions due to the ability of subjects to selectively attend word aspects of the stimuli under reading response conditions, differences between groups were probably in efficiency or effectiveness of selectivity rather than in use of different operations. Likewise, if the Unrelated Word Interference conditions provided a response selection cue unavailable in Stroop Interference condition, which facilitated responding, all subject groups appeared to make use of this cue to some extent.

All interference tasks in this study required selection between two relevant responses. The benefit derived from either selective attention to stimulus aspect or greater discriminability of elicited responses was facilitation of the selection of appropriate response and/or inhibition of the inappropriate response. The differentially slower response times of old subjects in both modified interference conditions, as well as in the usual Stroop interference condition, may have indicated a reduced ability to selectively attend stimulus aspect, to utilize the response set "cue", and/or to inhibit responses selected as inappropriate; however, the lack of evidence of age differences in non-interference conditions argued against both "early" perceptual and "late" motor component differences as the source of age differences. If older subjects were less able to selectively attend stimulus aspect at early perceptual processing stages due to more diffuse attention, greater inter-item interference might also be expected in the non-interference conditions. Similarly, if response production required more time for old subjects, age differences across conditions would have occurred.

The naming response to words has been described as being available prior to the naming response to color due to differences in the compatibility of stimulus and response in the two associations (Treisman and Fearnley, 1969), or to differences in time course for processing (Dyer, 1973; Posner, 1978). As there was no indication in the age differences effect observed that old and younger adults differed with respect to relative availability of word and color naming responses, there was no support for either differences

between groups in relative strengths of association, or in relative time courses for the processing of word or color information. However, as was noted above, the stimulus conditions and response measures used in this study were not sensitive indices of time course differences.

A commonality of interference conditions, regardless of relation between stimulus aspects or response requirements, was the requirement that subjects select between alternative responses. Although the responses were assumed to differ with respect to availability, in the color/word condition both color and word information have been assumed to be processed to some extent, and therefore both color-name and word-name responses would have some probability of being coded and emitted. The differences in the performance of age groups in the present study did not indicate differences across age groups in the probability of the "correct" response being emitted, as error rates were quite low for all subjects (i.e., 1-3 self-corrected errors per trial, no differences between age groups). However, the age differential interference effect may be in the selection between elicted responses.

If old adults either process or utilize response selection cues less efficiently, the selection of appropriate response would be expected to require more processing time. Despite considerable speculation (Botwinick, 1973) and some evidence (Kline and Orme-Rogers, 1978) regarding age related deficits in inhibitory function, in the present study there was no direct evidence that old subjects experienced greater difficulty "inhibiting" the inappropriate response. The slower response times, associated with all experimental

conditions requiring selection between responses, appeared most consonant with slowing of central "decision" processes. Although this interpretation can only be speculative, as the experimental procedure did not permit discrimination between processing stages, it would be consistent with prior research in which aged subjects have demonstrated relatively greater slowing in central processes than in peripheral (e.g., perception, motor response) processes. Gaylord and Marsh (1975) described slowing in both "central" and "residual" processes in their study contrasting old and young subjects on a choice reaction time task which required mental rotation of a geometric figure. However, the results reported indicated greater age differences in "central" processing time (i.e., older subjects 139% longer than young subjects), than in "residual" processing time (i.e., older subjects 84% longer than young subjects). Similarly, in the present study, aged adults demonstrated longer response times across conditions; however, the age differences in response times were between 7% and 16% greater in conditions which could be described as requiring discrimination and choice between reponses.

Although the age differences in performance on Stroop Tasks appeared to be attributable to age differential interference effects, with old subjects demonstrating greater interference effects, the Stroop Tasks do not provide a particularly sensitive method of analyzing the nature of age differences in information processing. The "interference proneness" of elderly subjects might be better examined with Stroop stimuli presented singly, with pre-exposure of word attribute for variable intervals prior to coloration (e.g., Dyer, 1973)

The pre-exposure method, contrasting age groups on a range of intervals, would provide evidence regarding the relative time courses for maximum interference as measured by response latency; however, in view of evidence of age-related slowing in perceptual, contral and motor responses, speculative differential slowing in central processing could possibly best be examined in experimental paradigms permitting discrimination of processing stages. The choice reaction time method used by Gaylord and Marsh provided a means of partitioning "cognitive" and "residual" reaction times in one response time measure. An alternative to this approach, suggested by evidence from the present study of the feasibility of matching subjects of different age groups on response times in non-interference conditions, would be to match subjects on simple reaction time tasks prior to contrast on choice reaction time tasks.

The results from the present study have been interpreted as indicative of age differences in interference effects. Research interest in adult age differences has been directed by interest in the process of aging, and implications of aging processes on behavior. As this study, and most of the related research, was conducted using cross-sectional comparison methods, the extent to which results describe changes attributable to increasing age is of interest. Although considerable methodological debate has been generated regarding the generalizability of cross-sectional results (e.g., Goulet and Baltes, 1970; Nesselroade and Reese, 1973; Birren and Renner, 1977) the efficiency and economy of the design in contrast to longitudnal (i.e., repeated measures of "aging" subjects) or cross-sequential (i.e., repeated measures from subjects of the same age cohort)

encouraged continued use of cross-sectional data in making "aging" interpretations. Schonfield (1975) has pointed out that selection and matching criterion can eliminate many alternative explanations of age group differences. In addition, Arenberg and Robertson-Tchabo (1977), evaluating results from both longitudnal and cross-sectional "aging" studies in learning, noted that findings were not discrepant.

Within experimental areas examining behavior relatively unaffected by social variables (e.g., perception, learning, memory) replicated cross-sectional results would be expected to be representative of changes with age; however, the semantic discrimination between age differences research and aging research remains valid.

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APPENDIX A: FIGURES

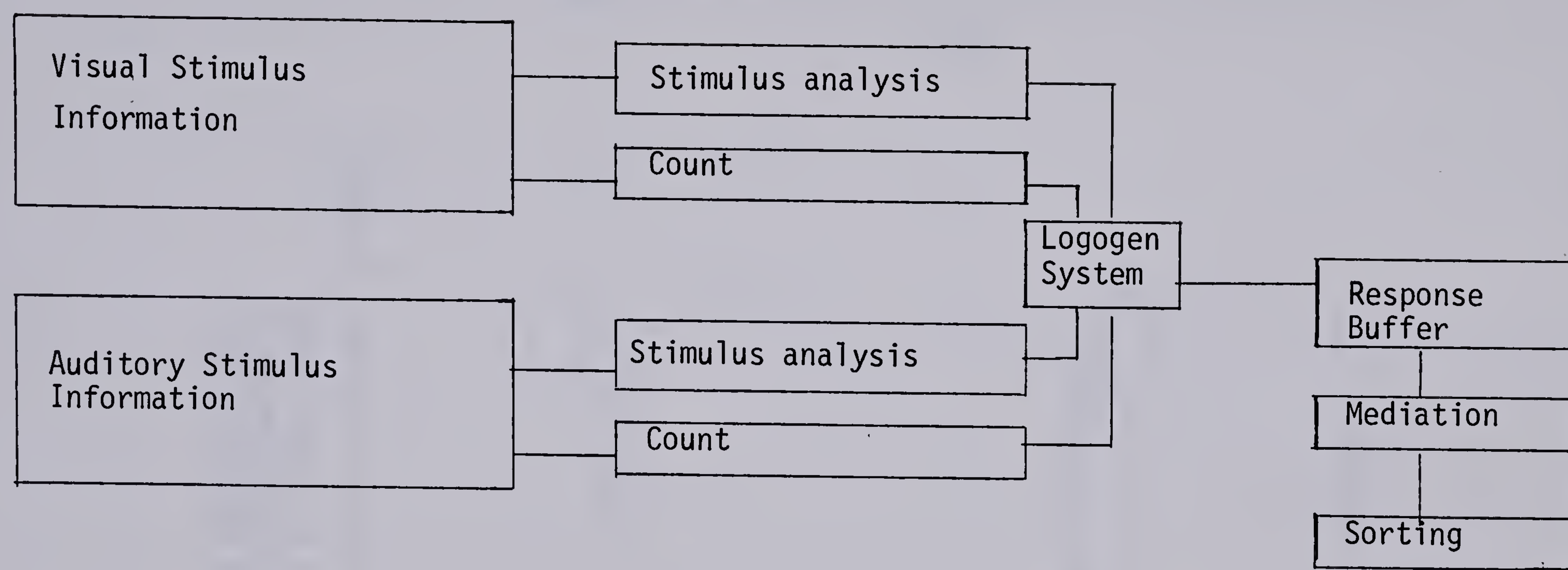

FIGURE 1. Logogen Model of Information Processing Operations. From Morton, J. Categories of interference: Verbal mediation and conflict in card-sorting. British Journal of Psychology, 1969, 60(3), p.339.

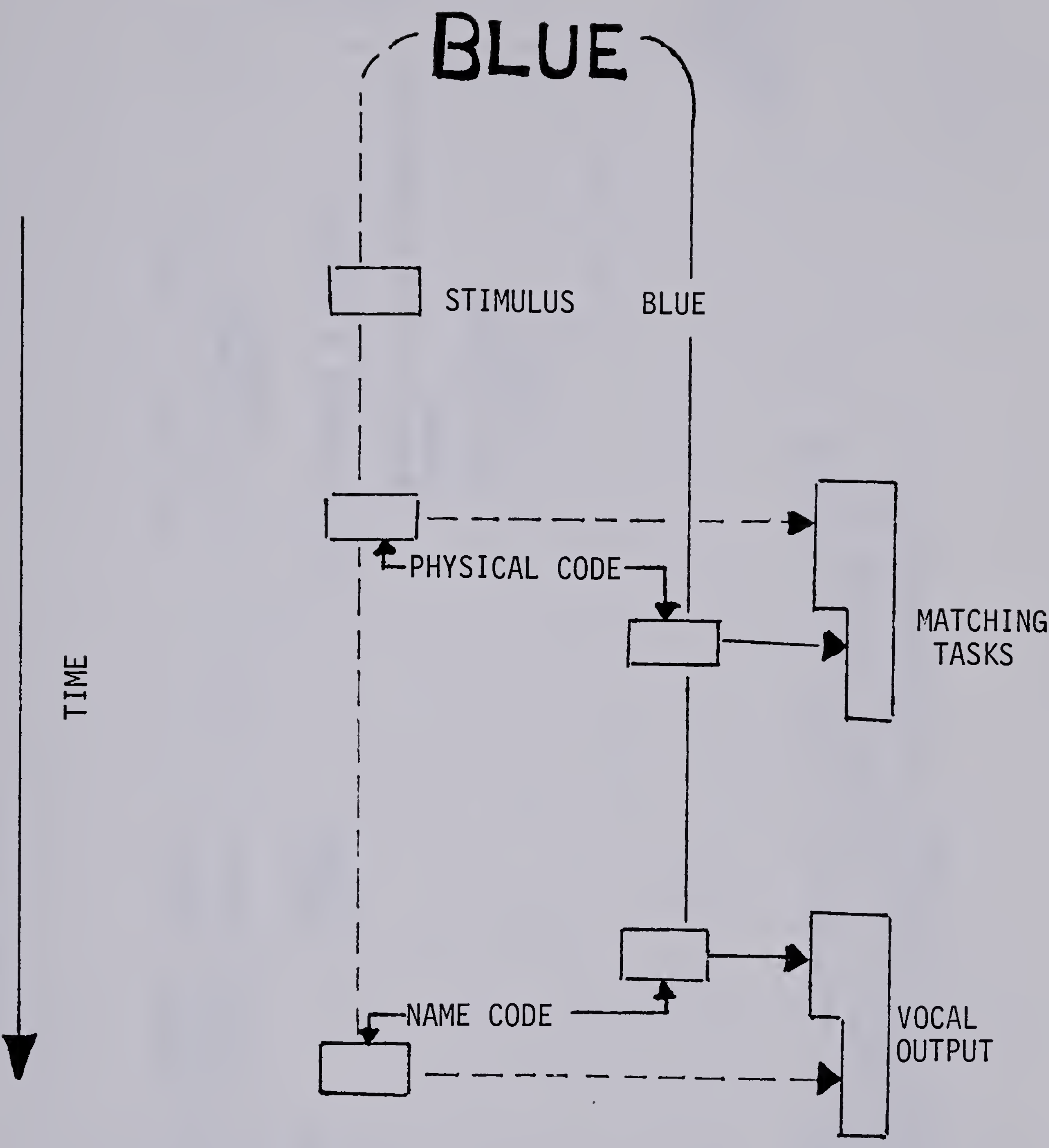

FIGURE 2: Schematic of the Stroop Effect

From Posner, M.I. Chronometric Explorations of Mind. New York: John Wiley and Sons, 1978.

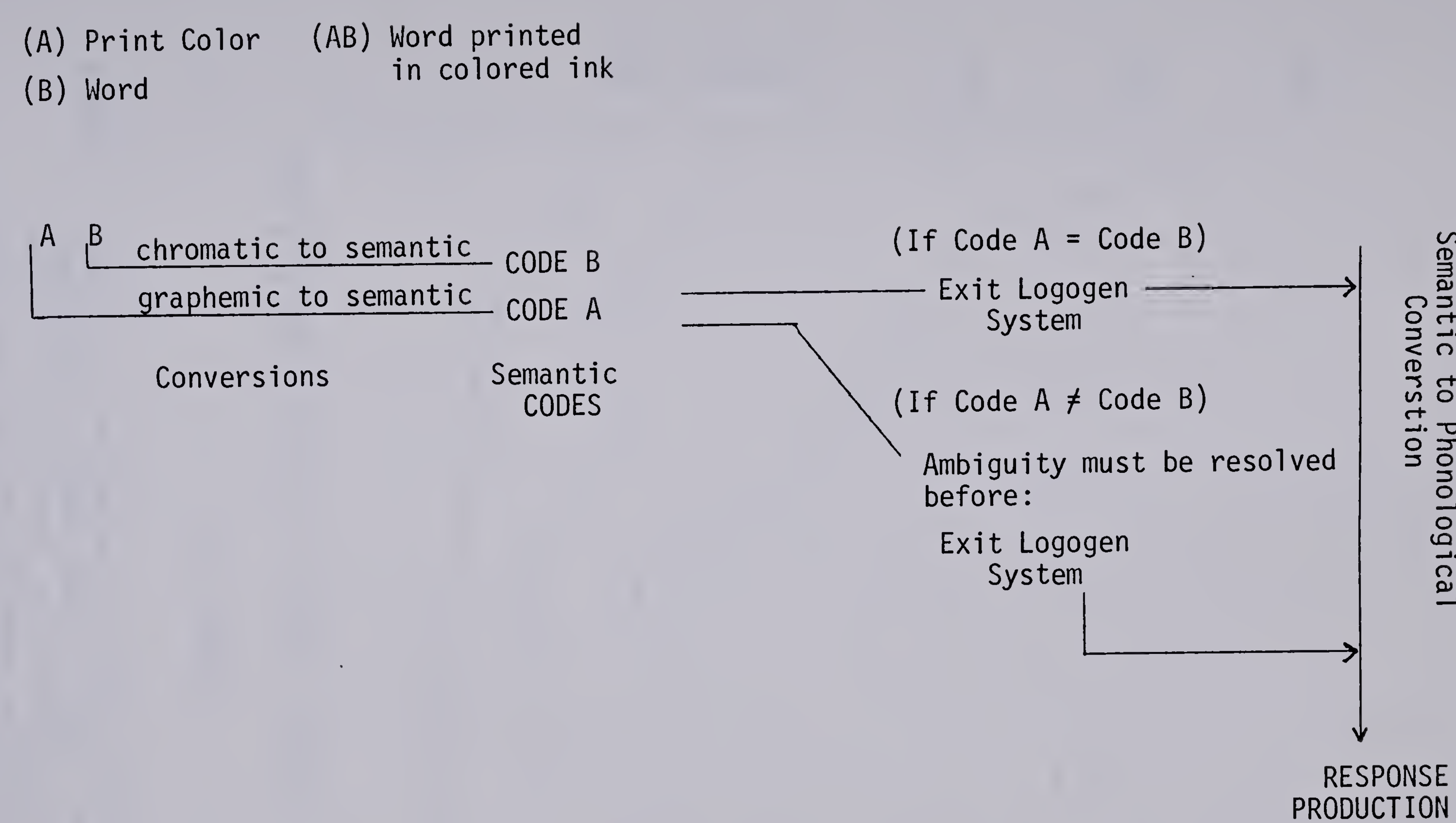

FIGURE 3. Schematic representation of Conceptual Encoding From Seymour, P.H.K. Conceptual encoding and locus of the Stroop Effect. Quarterly Journal of Experimental Psychology. 1977, 29, 245-265.

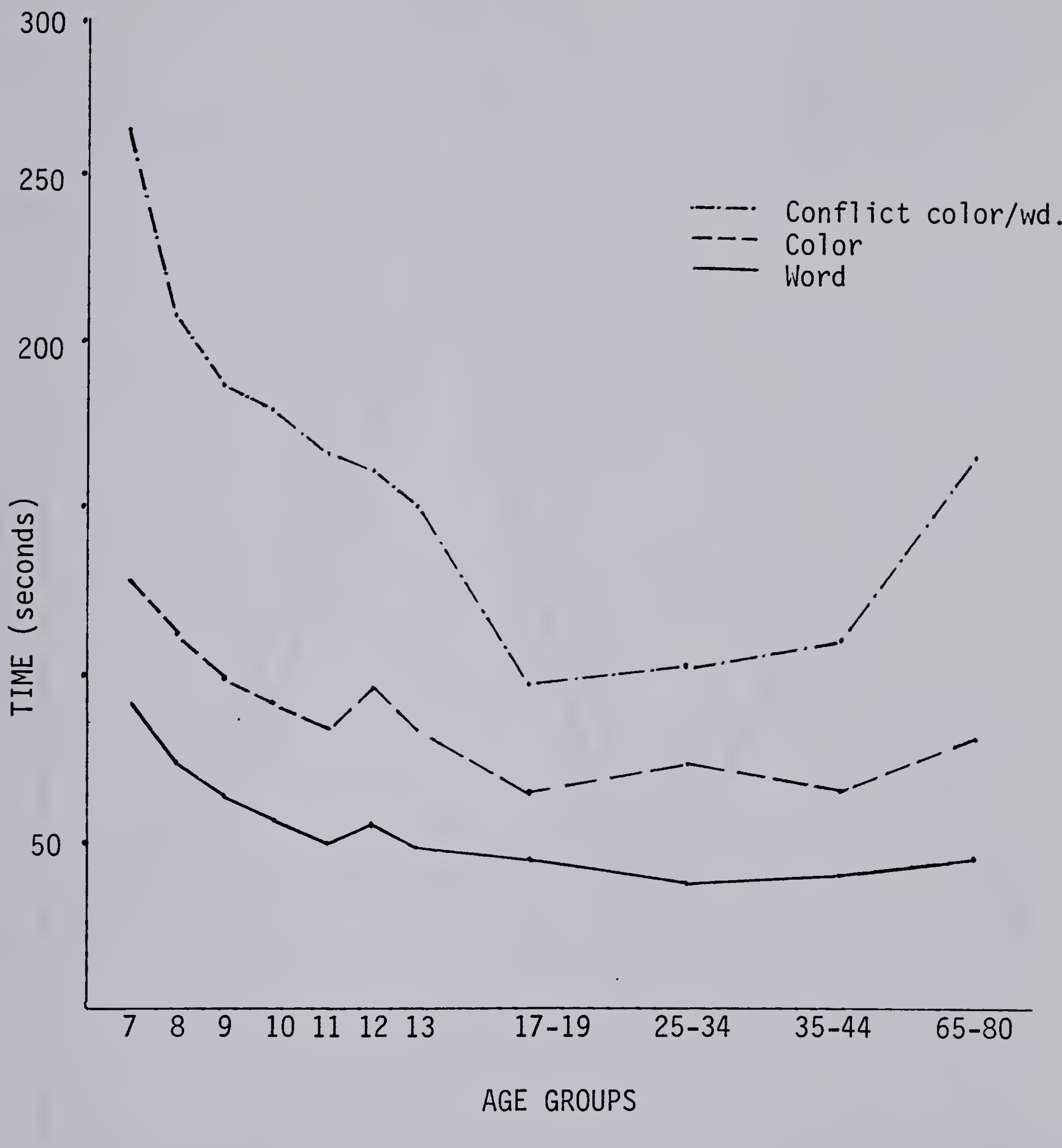

FIGURE 4. Changes in performance on Stroop Color-Word Test from seven to eighty years of age. From Comalli, P.E. Wapner, S. and Werner, H. Interference effects of Stroop color-word test in childhood, adulthood, and aging. The Journal of Genetic Psychology, 1962, 100, p.49.

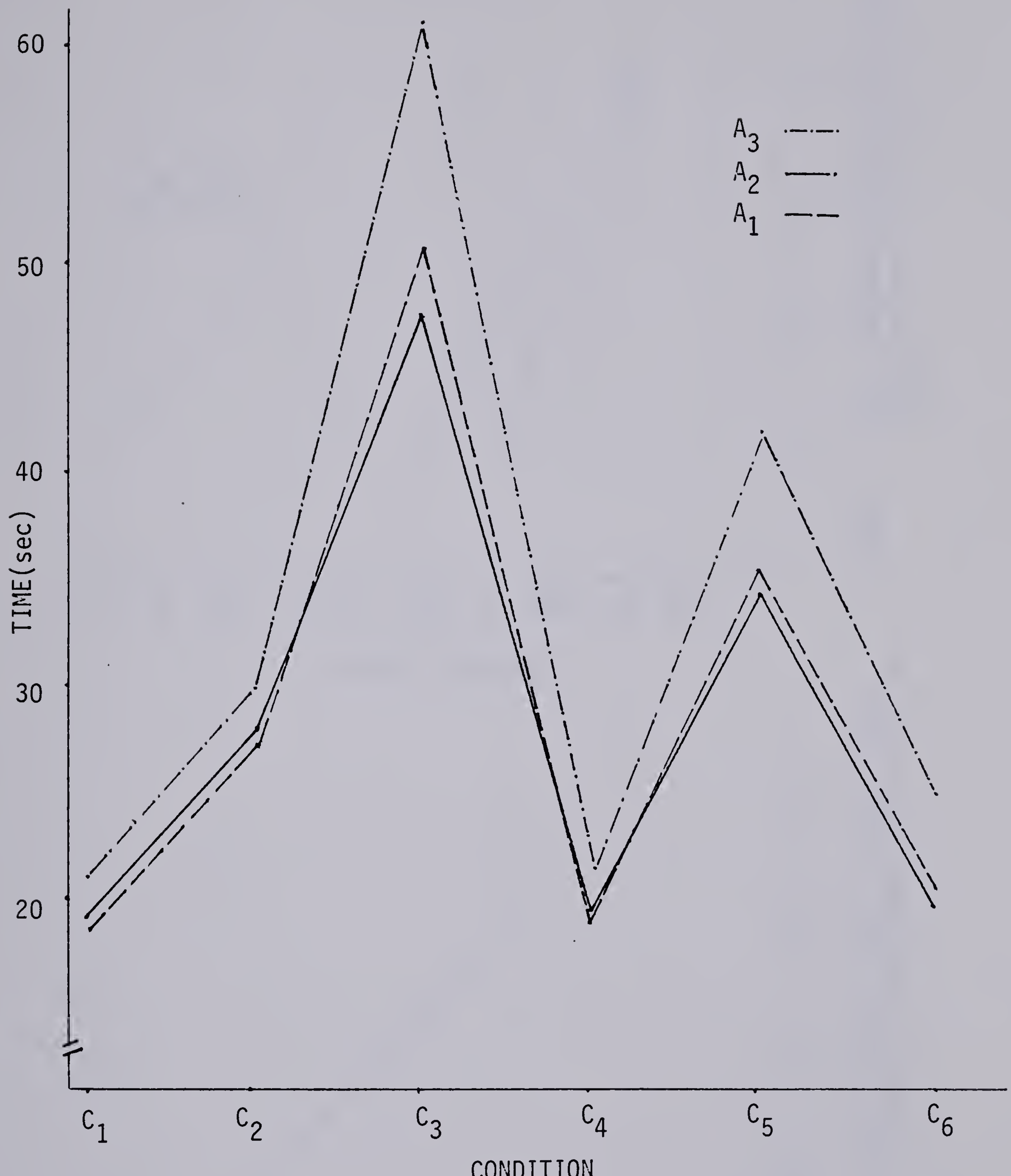

FIGURE 5: Mean Response Times for Each Age Group, on Each of Six Experimental Conditions, Averaged over Trials.

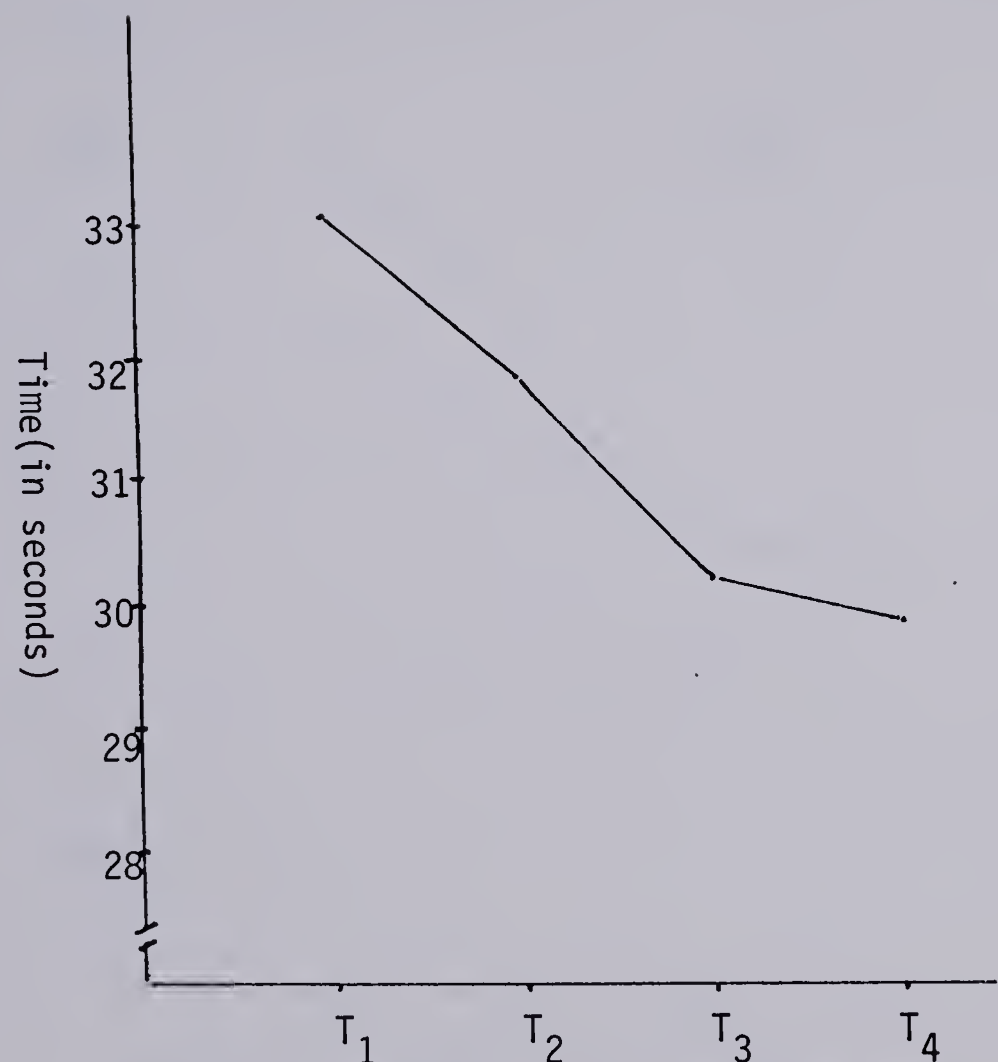

FIGURE 6: Trials effect. Times for each Trial, averaged over Age Groups and Condition.

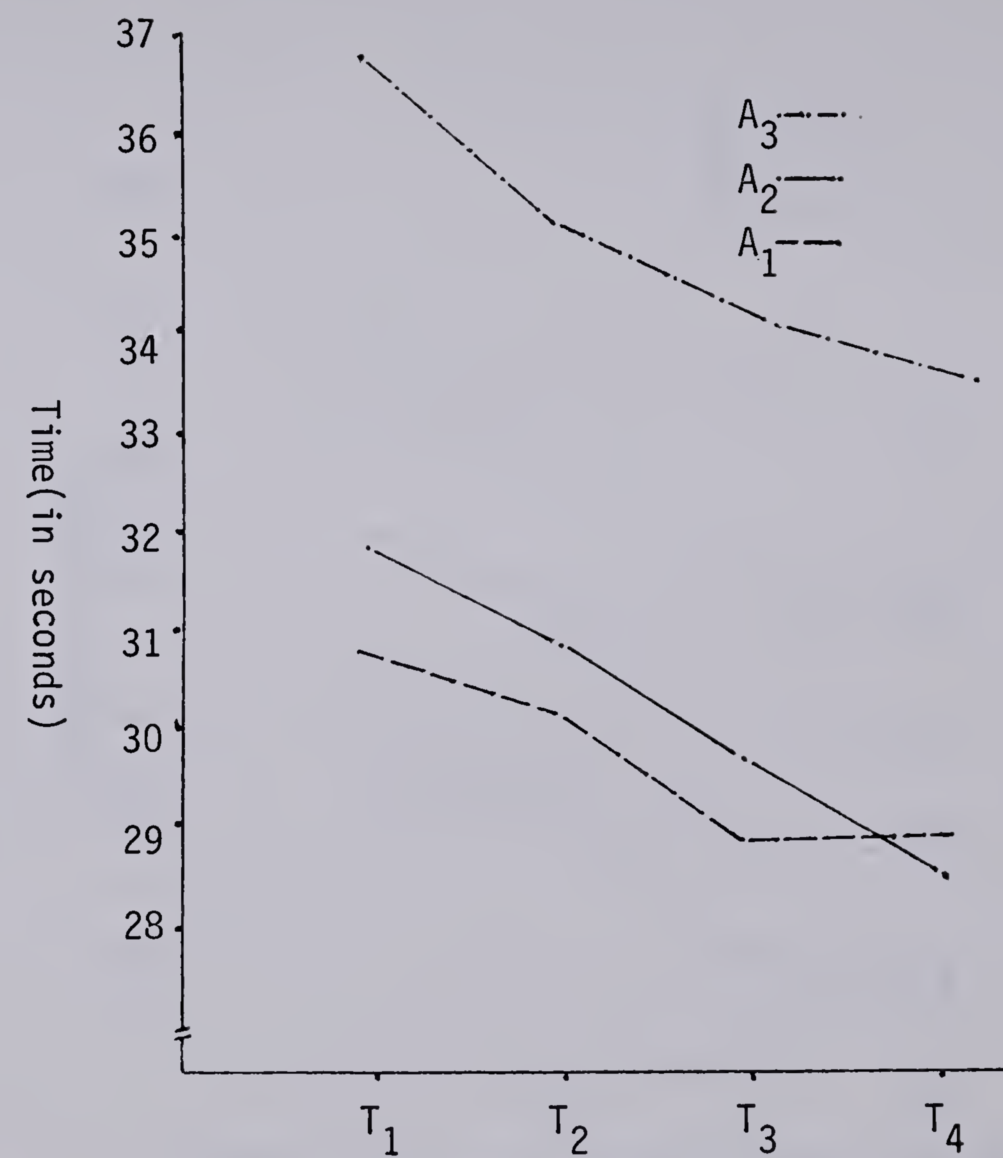

FIGURE 7: Mean response times for Age Groups, averaged over Conditions, across Trials.

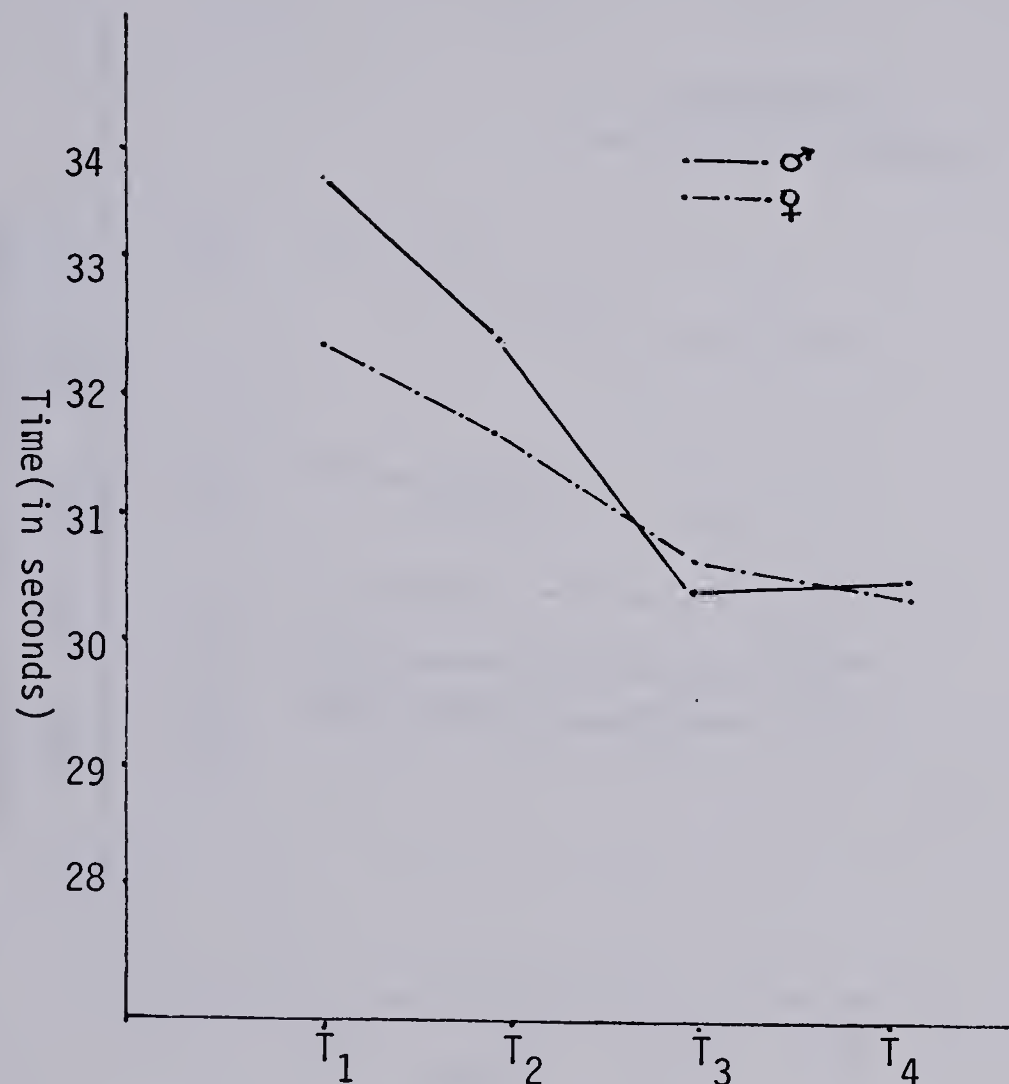

FIGURE 8: Response Times for Males and Females across Trials, averaged over Age Group, and Condition.

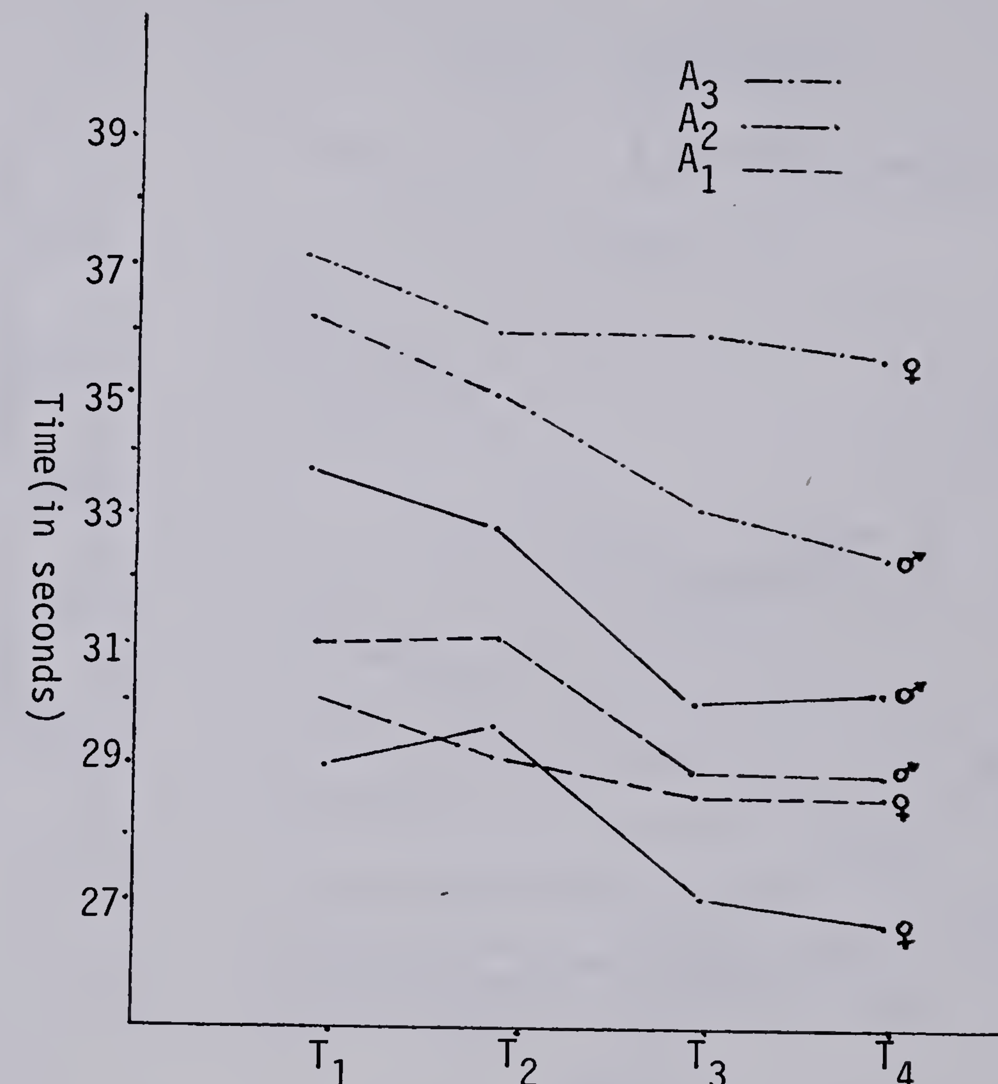

FIGURE 9: Response Times for Males and Females of three Age Groups, across Trials, averaged over Condition.

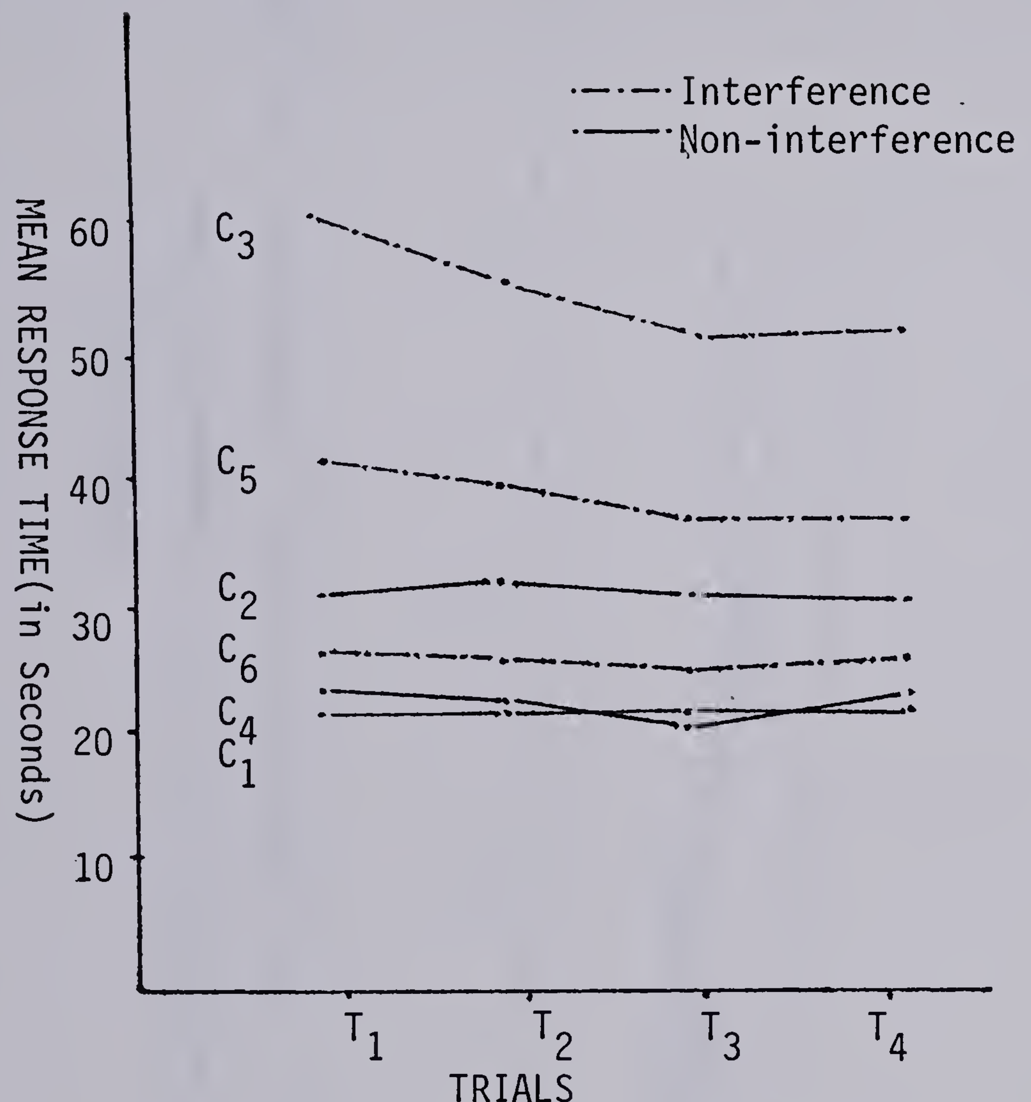

FIGURE 10: Mean Response Times for Each of Six Conditions, Averaged Over 48 Subjects, Across Four Trials

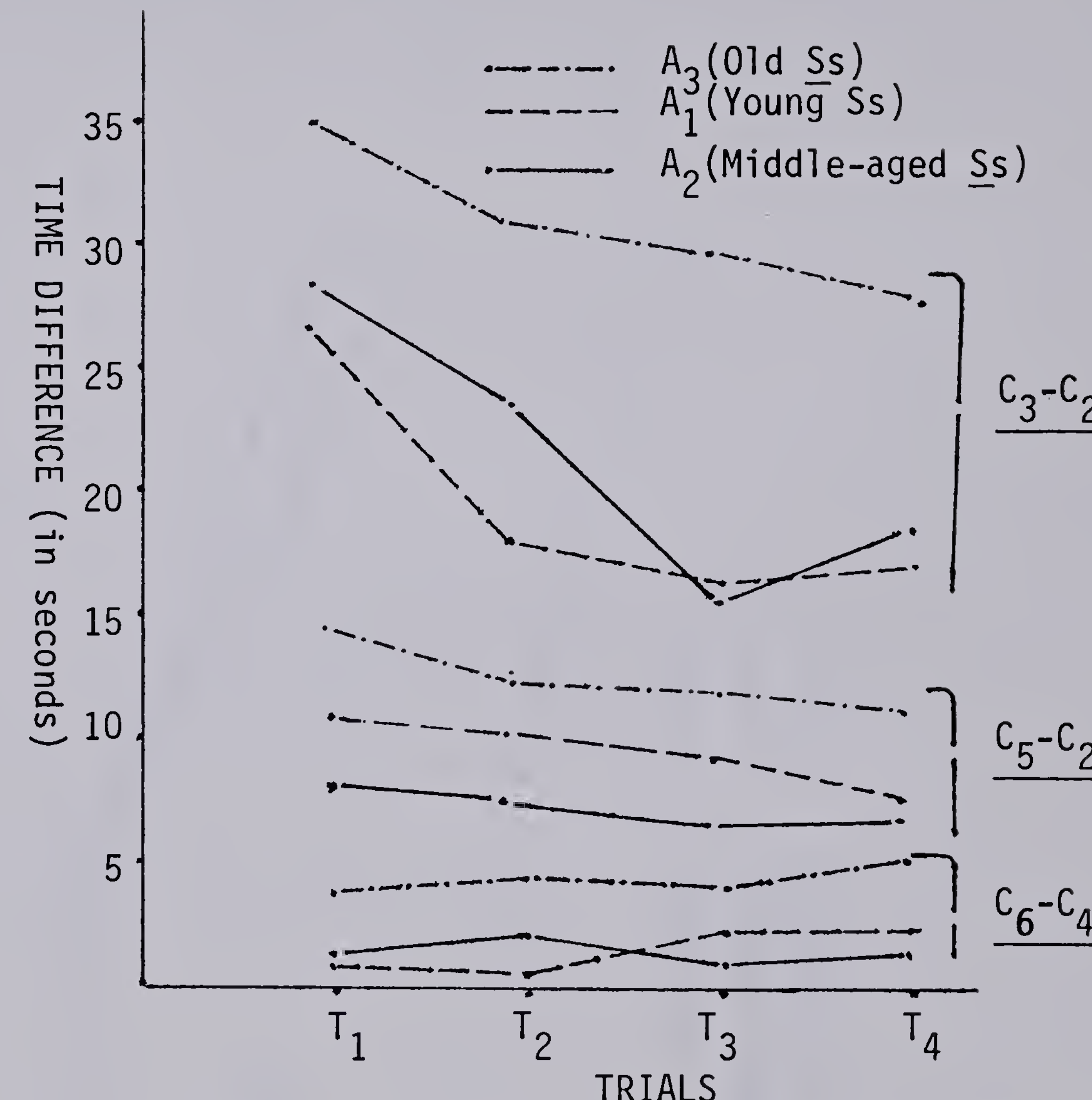

FIGURE 11: Contrast of Three Age Groups on Derived Score Interference Effects, Across Four Trials.

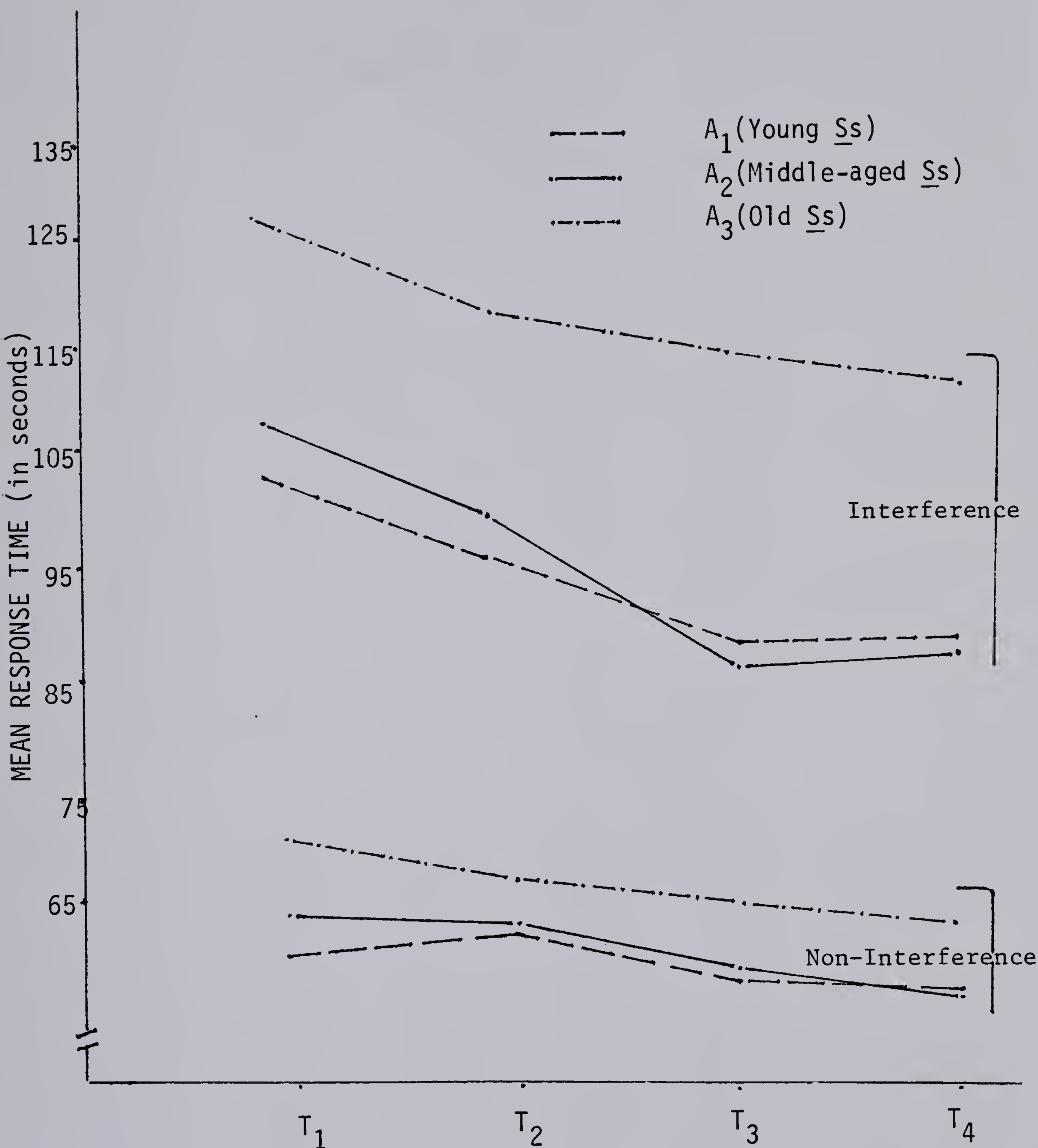

FIGURE 12: Mean Response Times for three Age Groups, Averaged Over Interference Vs. Non-Interference Conditions Across Four Trials.

APPENDIX B

1.	<u>NUDGE</u>	SLAB	COIL	ROLL	PUSH
2.	<u>QUIRK</u>	FAST	FATE	RILE	TURN
3.	<u>TRESS</u>	HAIR	ROBE	IRON	HURT
4.	<u>GRADE</u>	SHOP	CURL	SORT	FEAR
5.	<u>CRANK</u>	AUTO	TIER	LINE	TURN
6.	<u>TRIAL</u>	MOST	GAME	TYPE	TEST
7.	<u>WINCH</u>	SNUB	REEL	LONG	TAPE
8.	<u>TRACT</u>	AREA	DRAW	PULL	PACT
9.	<u>SCOUT</u>	RISK	KIND	MALE	LOOK
10.	<u>MOOCH</u>	LOAF	MUCH	ROMP	SPRY
11.	<u>NOBLE</u>	BILL	HIGH	GOLD	RING
12.	<u>AFFIX</u>	GAIN	POST	TIRE	MEND
13.	<u>TUNIC</u>	SONG	CLAN	FISH	ROBE
14.	<u>VOUCH</u>	BACK	SOFA	FREE	ACHE
15.	<u>ASSAY</u>	RANT	DOLT	TEST	READ
16.	<u>TOOTH</u>	FANG	EASE	SMUG	TWIN
17.	<u>PICOT</u>	SODA	LOOP	JERK	ATOM
18.	<u>TWEAK</u>	LAME	FALL	JERK	WICK
19.	<u>STUNT</u>	FEAT	CRAG	JUMP	JOKE
20.	<u>EJECT</u>	STOP	OUST	VOTE	PULL
21.	<u>AGONY</u>	HARM	AWAY	PAIN	ERAL
22.	<u>PHASE</u>	SIDE	HUNT	WORD	SPAR
23.	<u>HAUNT</u>	BEST	GAME	BULB	NEST
24.	<u>BRISK</u>	BOLD	FAST	TIDY	NEAT
25.	<u>IMAGE</u>	DULL	PATE	ICON	SIRE

26.	<u>SHARE</u>	PART	MEAL	COIL	LAND
27.	<u>FEINT</u>	MOCK	WEAK	PALE	FALL
28.	<u>TALLY</u>	SIFT	GLEE	AIDE	MARK
29.	<u>DROOP</u>	IOTA	WILT	DOWN	BITE
30.	<u>DROLL</u>	TART	TURN	JEST	DRUM
31.	<u>SNEAK</u>	SHOE	TALK	LURK	OOZE
32.	<u>REBEL</u>	RING	RISE	BEST	HATE
33.	<u>STOKE</u>	POST	POKE	BOMB	SHIP
34.	<u>BLAST</u>	TOOT	HOLY	LUSH	GONE
35.	<u>CINCH</u>	FAST	EDGE	LIMP	GRIP
36.	<u>STACK</u>	PILE	POLE	BEND	NAIL
37.	<u>BOOTY</u>	SHOE	FIND	SWAG	FINE
38.	<u>SCOFF</u>	HURT	JEER	LOSE	LUNG
39.	<u>QUOTE</u>	ROOT	PART	CITE	SITE
40.	<u>AWFUL</u>	LOAD	FEAR	DIRE	VAST
41.	<u>SHRUB</u>	WASH	RASP	BUSH	TREE
42.	<u>STUFF</u>	LOUT	HARD	CRAM	JUNK
43.	<u>STILT</u>	LEAN	POLE	LONG	CANE
44.	<u>MODEL</u>	CHIC	TYPE	POEM	ROOK
45.	<u>SMART</u>	CHIC	GOOD	NICE	MODE
46.	<u>HUMOR</u>	PLUS	BOIL	MOOD	PLAY
47.	<u>SLINK</u>	JOIN	LURK	DARK	MURK
48.	<u>SCREW</u>	BRAY	IRON	RIFT	TURN
49.	<u>PIVOT</u>	TURF	GOLF	TURN	BONE
50.	<u>DUMMY</u>	JOKE	GOOD	COPY	SLOW

STIMULUS CARDS

CARD 1: Color words printed in black ink

Color words: YELLOW, BLUE, RED, BROWN and GREEN, were each printed 10 times, twice in each of five rows of 10 words, in black in.

CARD 2: Color patches

Solid rectangular color patches, in ink colors yellow, blue, red, brown and green, each measuring .5 cm X 2.5 cm were printed 10 times each, twice in each of 5 rows of 10 color patches.

CARD 3: Color words printed in incongruent ink color

Color name words: YELLOW, BLUE, RED, BROWN, and GREEN, were printed 10 times each, twice in each of 5 rows of 10 words, in colored ink. Each of the five color words appeared at least once in each of the four incongruent ink colors, with each ink color appearing twice in each row.

CARD 4: Color words printed in congruent ink color

Color name words: YELLOW, BLUE, RED, BROWN, and GREEN, were printed 10 times each, twice in each of five rows of 10 words, in colored ink. Each of the five color words appeared in the ink color represented by the color name.

CARD 5: Non-color words printed in colored ink

Verbs: LISTEN, SERVE, ASK, DANCE and CAME were printed 10 times each, twice in each of five rows of 10 words, in colored ink. Each verb was printed at least once in each of the five colors, with each of the five colors appearing two times in each row. The verbs used were selected to match color words in frequency of usage (based on Thorndike-Lorge Word Count, 19), and for their lack of association with color meaning.

APPENDIX C: TABLES

TABLE 1: Summary of Analysis of Variance, Subjects Nested in Age Group and Sex, with Four Trials on Each of Six Experimental Conditions.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARE	F
A: Age Group	6454.09	2	3227.05	7.69**
B: Sex	94.58	1	94.58	-
A X B	1342.22	2	671.11	1.66
S(AB): Error	17020.42	42	405.25	
C: Condition	166858.46	5	33371.69	656.02**
A X C	3920.96	10	392.10	7.71**
B X C	117.32	5	23.46	-
A X B X C	294.78	10	29.48	-
S(AB) X C	10681.59	210	50.87	
T: Trial	1671.10	3	557.03	83.01**
A X T	115.16	6	19.19	2.86*
B X T	93.36	3	31.12	4.64**
A X B X T	69.30	6	11.55	1.72
S(AB) X T	845.80	126	6.71	
C X T	1361.48	15	90.77	13.71**
A X C X T	199.08	30	6.64	1.00
B X C X T	122.18	15	8.15	1.23
A X B X C X T	70.01	30	2.34	-
S(AB) X C X T	4168.07	630	6.62	
TOTAL	215500.05	1151		

*p .05
**p .01

TABLE 2: Means and Standard Deviations of Response Times for Six Conditions, Three Age Groups, Averaged Over Subjects and Trials.

AGE GROUP	CONDITION C_1	C_2	C_3	C_4	C_5	C_6	
A_1 (young Ss)	20.26	28.37	49.04	20.62	36.86	21.96	Mean
	2.30	5.01	8.71	2.81	7.73	3.66	s.d.
A_2 (middle-aged Ss)	20.33	29.26	51.44	20.47	36.18	21.78	Mean
	4.43	4.15	6.11	2.75	4.81	2.51	s.d.
A_3 (old Ss)	22.02	31.38	62.71	22.39	43.65	26.20	Mean
	2.67	4.55	9.36	2.96	9.76	3.89	s.d.

TABLE 3: Duncan's Multiple Range Test on Age Group Mean Response Times for Each of Six Conditions, Averaged over Subjects and Trials.

	A_1C_1	A_2C_1	A_2C_4	A_1C_4	A_2C_6	A_1C_6	A_3C_1	A_4C_3	A_3C_6	A_1C_2	A_2C_2	A_3C_2	A_2C_5	A_1C_5	A_3C_5	A_1C_3	A_2C_3	A_3C_3
C_1A_1 20.26	20.26	20.33	20.47	20.62	21.78	21.96	22.02	22.39	26.20	28.37	29.26	31.38	36.18	36.86	43.65	49.04	51.44	62.71
C_1A_2 20.33		.07	.21	.36	1.52	1.70	1.76	2.13	5.94	8.11	9.00	11.12	15.92	16.60	23.39	28.78	31.18	42.45
C_4A_2 20.47			.14	.29	1.45	1.63	1.69	2.06	5.87	8.04	8.93	11.05	15.85	16.53	23.32	28.71	31.11	42.38
C_4A_1 20.62				.15	1.31	1.49	1.55	1.92	5.73	7.90	8.79	10.91	15.85	16.39	23.18	28.57	30.97	42.24
C_6A_2 21.78					1.16	1.34	1.40	1.77	5.58	7.75	8.64	10.76	15.71	16.24	28.03	28.42	30.62	42.09
C_6A_1 21.96						.18	.24	.61	4.42	6.59	7.48	9.60	14.40	15.08	21.87	27.26	29.66	40.93
C_1A_3 22.02							.06	.43	4.24	6.41	7.30	9.42	14.22	14.90	21.69	27.08	29.48	40.75
C_4A_3 22.39								.37	4.18	6.35	7.24	9.36	14.16	14.84	21.63	27.02	29.42	40.69
C_6A_3 26.20									3.81	5.98	6.87	8.99	13.79	14.47	21.26	26.65	29.05	40.32
C_2A_1 28.37										2.17	3.06	5.18	9.98	10.66	17.45	22.84	25.24	36.51
C_2A_2 29.26											.89	3.01	7.81	8.49	15.28	20.67	23.07	34.34
C_2A_3 31.38												2.12	6.92	7.60	14.39	19.78	22.18	33.45
C_5A_2 36.18													4.80	5.48	12.27	17.66	20.06	31.33
C_5A_1 36.86														.68	7.47	12.86	15.26	26.53
C_5A_3 43.65															6.79	12.18	14.52	25.85
C_3A_1 49.04																5.39	7.79	19.06
C_3A_2 51.44																	2.40	13.67
C_3A_3 62.71																		11.27

C_1A_1 C_1A_2 C_4A_2 C_6A_2 C_6A_1 C_1A_3 C_4A_3 C_6A_3 C_2A_1 C_2A_2 C_2A_3 C_5A_2 C_5A_1 C_5A_3 C_3A_1 C_3A_2 C_3A_3 C_3A_3

R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}	R_{17}	R_{18}
3.24	3.38	3.47	3.54	3.60	3.64	3.68	3.71	3.74	3.77	3.79	3.81	3.83	3.85	3.87	3.88	3.90

TABLE 4: RATIOS OF AGE GROUP MEANS, AVERAGED OVER FOUR TRIALS, ACROSS CONDITIONS.

RATIOS	CONDITIONS					
	Non-Interference			Interference		
	C_1	C_2	C_4	C_3	C_5	C_6
A_2/A_1	1.00	1.03	.98	1.05	.98	.99
A_3/A_1	1.09	1.11	1.08	1.27	1.18	1.19
A_3/A_2	1.08	1.07	1.09	1.22	1.20	1.20

A_1: Young Subjects, aged 16-25
A_2: Middle-aged Subjects, aged 35-50
A_3: Old Subjects, aged 64-78

TABLE 5: Summary Of Analysis Of Variance On Difference Scores: C_3-C_2. Within and Between Age Groups, Averaged over Trials.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	1034.94	2	517.47	14.84**
Within Groups	1569.08	45	34.87	
TOTAL	2604.02	47		

**p< .01

Multiple Comparison on Difference Score Sums: Scheffe's Test for Significant Differences in Mean Square Sums of Three Age Groups on C_3-C_2 Scores.

Comparison	ΣX_{A_1} 330.78	ΣX_{A_2} 360.65	ΣX_{A_3} 501.18	$\Sigma a_{.i}^2$	D_i	D_i^2	MS_{D_i}	
A_1 vs. A_2	-1	1	0	2	29.87	892.22	27.88	n.s.
A_1 vs. A_3	-1	0	1	2	170.40	29036.16	907.38	**
A_2 vs. A_3	0	-1	1	2	140.53	19748.68	617.15	**
A_1+A_2 vs. A_3	1	1	-2	6	190.25	36195.06	377.03	**

Least Significant MS_{D_i} (α = .01) = 356.37 **p< .01

A_1 = Young Subjects; A_2 = Middle-Aged Subjects; A_3 = Old Subjects

TABLE 6: Summary of Analysis of Variance on Difference Scores: C_5-C_2, Within and Between Age Groups, Averaged over Trials.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	241.48	2	120.74	5.95**
Within Groups	913.87	45	20.31	
TOTAL	1155.35	47		

**p < .01

Multiple Comparison on Difference Score Sums: Scheffés Test for Significant Differences in Mean Square Sums on C_5-C_2 Scores for Three Age Groups.

Comparison	ΣX_{A_1} 135.84	ΣX_{A_2} 110.69	ΣX_{A_3} 196.21	$\Sigma a_{.i}^2$	D_i	D_i^2	MS_{D_i}
A_1 vs. A_2	1	-1	0	2	25.15	632.52	19.77 n.s.
A_1 vs. A_3	1	0	-1	2	60.37	3644.54	113.89 n.s.
A_2 vs. A_3	0	-1	1	2	85.62	7313.67	228.55 **
A_1+A_2 vs. A_3	1	1	-2	6	50.32	2532.10	26.38 n.s.

Least Significant MS_{D_i} (α =.01) = 207.57 **p < .01

Least Significant MS_{D_i} (α =.05) = 130.39

A_1 = Young Subjects; A_2= Middle-aged Subjects; A_3= Old Subjects.

TABLE 7: Summary of Analysis of Variance on Difference Scores: C_6-C_4, Within and Between Age Groups, Averaged over Trials.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	65.89	2	32.95	7.79^{**}
Within Groups	190.34	45	4.23	
TOTAL	256.23	47		

$^{**}p < .01$

Multiple Comparison on Difference Score Sums: Scheffe's Test for Significant Differences in Mean Square Sums on C_6-C_4 Scores for Three Age Groups.

Comparison	ΣX_{A_1} 21.53	ΣX_{A_2} 21.10	ΣX_{A_3} 61.08	$\Sigma a_{.i}^2$	D_i	D_i^2	MS_{D_i}	
A_1 vs. A_2	1	-1	0	2	.43	.19	.006	n.s.
A_1 vs. A_3	-1	0	1	2	39.55	1564.2	48.88^{**}	
A_2 vs. A_3	0	-1	1	2	39.98	1598.4	49.95^{**}	
$A_1 + A_2$ vs. A_3	-1	-1	2	6	79.53	6325.0	65.89^{**}	

Least significant MS_{D_i} ($\alpha = .01$) = 43.23 $^{**}p < .01$

A_1 = Young Subjects; A_2 = Middle-aged Subjects; A_3 = Old Subjects.

TABLE 8: Summary of Analysis of Variance on Ratio Scores: C_1/C_2, Within and Between Age Groups, Averaged over Trials.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	.005	2	.0025	<1.00 n.s.
Within Groups	.238	45	.0053	
TOTAL	.243	47		

Multiple Comparison on Ratio Sums: Scheffe's Test for Significant Differences in Mean Square Sums on C_1/C_2 Ratios for Three Age Groups.

Comparison	ΣX_{A_1} 11.584	ΣX_{A_2} 11.232	ΣX_{A_3} 11.312	$\Sigma a^2_{.i}$	D_i	D_i^2	MS_{D_i}	
A_1 vs. A_2	1	-1	0	2	.352	.124	.004	n.s.
A_1 vs. A_3	1	0	-1	2	.272	.074	.002	n.s.
A_2 vs. A_3	0	-1	1	2	.080	.006	.0002	n.s.
A_1+A_2 vs. A_3	1	1	-2	6	.192	.037	.0003	n.s.

Least significant MS_{D_i} ($\alpha = .01$) = .051

Least significant MS_{D_i} ($\alpha = .05$) = .032

TABLE 9: Summary of Trend Analysis on Trials, By Sex and Age Group.

SOURCE	SUM OF SQUARES	DF	MEAN SQUARES	F
Linear Component:	1585.29	1	1585.29	236.26**
A X L	63.58	2	31.79	4.74*
B X L	65.91	1	65.91	9.82**
A X B X L	35.29	2	17.65	2.63n.s.
Group X Linear	164.78	5		
Quadratic Component:	64.40	1	64.40	9.60**
A X Q	6.19	2	3.10	-
B X Q	9.32	1	9.32	1.39n.s.
A X B X Q	19.53	2	9.77	1.46n.s.
Group X Quadratic	35.04	5		
S(AB) X Trials	845.80	126	6.71	

*$p < .05$
**$p < .01$

TABLE 10: Summary of Analysis of Variance on Difference Scores: C_3-C_2, on Trial Four Data Only.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	992.99	2	496.50	13.33**
Within Groups	1676.32	45	37.25	
TOTAL	2669.31	47		

**p < .01

Multiple Comparison on Difference Scores: C_3-C_2 Sums, Scheffes Test for Significant Differences in Mean Square Sums of Three Age Groups on Trial Four Data.

Comparison	$\sum X_{A_1}$ 295.72	$\sum X_{A_2}$ 316.77	$\sum X_{A_3}$ 459.54	$\sum a_{\cdot i}^2$	D_i	D_i^2	MS_{D_i}	
A_1 vs. A_2	-1	1	0	2	21.05	443.1	13.85	n.s.
A_1 vs. A_3	-1	0	1	2	163.82	26837.0	838.66**	
A_2 vs. A_3	0	-1	1	2	142.77	20383.3	636.98**	
A_1+A_2 vs. A_3	-1	-1	2	6	306.59	93997.4	979.14**	

Least Significant MS_{D_i} (α = .01) = 380.70 **p < .01

A_1 = Young Subjects; A_2= Middle aged Subjects; A_3 = Old Subjects.

TABLE 11: Summary of Analysis of Variance on Difference Scores: C_5-C_2, on Trial Four Data.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	242.79	2	121.39	5.29**
Within Groups	1032.22	45	22.94	
TOTAL	1275.01	47		

$^{**}p < .01$

Multiple Comparison on Difference Scores: C_5-C_2, Scheffe's Test for Significant Differences in Mean Square Sums for Three Age Groups on Trial Four.

	ΣX_{A_1} 99.84	ΣX_{A_2} 105.15	ΣX_{A_3} 178.69	$\Sigma a^2_{\cdot i}$	D_i	D_i^2	MS_{D_i}	
Comparison								
A_1 vs. A_2	-1	1	0	2	5.31	28.20	.88	n.s.
A_1 vs. A_3	-1	0	1	2	78.85	6217.30	194.29	*
A_2 vs. A_3	0	-1	1	2	73.54	5408.10	169.00	*
A_1+A_2vs.A_3	-1	-1	2	6	152.39	23222.7	241.90	**

Least Significant MS_{D_i} (= .05) = 147.39

Least Significant MS_{D_i} (= .01) = 234.45

$^{*}p < .05$
$^{**}p < .01$

A_1= Young Subjects; A_2= Middle Aged Subjects; A_3 = Old Subjects.

TABLE 12: Summary of Analysis of Variance on Difference Scores: C_6-C_4, on Trial Four Data only.

SOURCE	SUMS OF SQUARES	DF	MEAN SQUARES	F
Between Groups	78.27	2	39.14	4.38*
Within Groups	401.83	45	8.93	
TOTAL	480.10	47		

*p<.05

Multiple Comparison on Difference Score: C_6-C_4

Scheffes Test for Significant Differences in Mean Squares Sums for Three Age Groups on Trial Four Data.

Comparison	ΣX_{A_1} 27.05	ΣX_{A_2} 23.99	ΣX_{A_3} 68.78	$\Sigma a^2_{\cdot i}$	D_i	D_i^2	MS_{D_i}
A_1 vs. A_2	1	-1	0	2	3.06	9.36	.29 n.s.
A_1 vs. A_3	-1	0	1	2	41.70	1741.40	54.42 *
A_2 vs. A_3	0	-1	1	2	44.80	2006.10	62.69 *
A_1+A_2vs.A_3	-1	-1	2	6	86.50	7485.70	77.98 *

*p<.05

Least Significant MS_{D_i} (α = .05) = 28.47

Least Significant MS_{D_i} (α = .01) = 91.27

A_1 = Young Subjects; A_2 = Middle-aged Subjects; A_3 = Old Subjects.

TABLE 13 : Correlation Matrix of Experimental Factors

Rank Order Correlations Between Age and Six

Measures, Averaged over Four Trials for 48 Subjects

	Vocab.	Age	C_1	C_1/C_2	C_3-C_2	C_5-C_2	C_6-C_4
Vocab.		-.022	.080	.231	.130	.003	.304*
Age			.279	-.104	.540**	.421**	.366**
C_1				.056	.374**	.098	.042
C_1/C_2					.178	-.010	-.159
C_3-C_2						.527**	-.189
C_5-C_2							-.161
C_6-C_4							

* $p < .01$

** $p < .05$